THE FORESTER

A PRACTICAL TREATISE ON BRITISH FORESTRY AND ARBORICULTURE FOR LANDOWNERS, LAND AGENTS, AND FORESTERS

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To the

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The Fiftieth Anniversary of its Foundation

(1854-1904).

PREFACE.

ALTHOUGH based on the sixth edition of *The Forester* (1894), the book now published is in reality a new work, in which is incorporated, in a condensed and improved form, the essence of all the other books I have written on Forestry during the last thirteen years, together with much original matter dealing specially with conditions in the United Kingdom,—the whole forming a complete treatise giving full consideration both to theoretical principles and to practice. The only portions where any resemblance to Brown's *The Forester* could still be retained are (1) the two chapters now arranged as Part II., *The British Sylva;* (2) part of chapter vii., *Concerning Arboriculture*, in Part III.; and (3) some of the details regarding *Fencing* in Part IV., chapter ii. But all of these have been greatly altered from their original form; and the only parts of the old book that have been reproduced consist of a few extracts, mainly about practical work in former days, which I have quoted here and there, wherever appropriate.

These new volumes are intended to serve as a text-book dealing chiefly with British Forestry and Arboriculture (two really separate branches of Rural Economy, which have usually been synonymous in Britain), and with the reasonable possibilities there are of improving the existing condition of our woodlands, and of planting waste land for the growth of timber on business principles, with a fair prospect of profit. Such work, however, it is hardly reasonable to expect will ever be done, unless undertaken by the State itself, or with substantial assistance given to landowners, as is the case with the planting of wind-swept waste tracts in Denmark and Prussia. The book thus differs entirely, both in its specific aim and in the handling of the matter it contains, from the only other complete manual of modern Forestry as yet published in Britain. But as the subject cannot be treated thoroughly, more especially as regards the scientific facts which explain the theory and practice of Forestry, without making use of the knowledge acquired in Continental countries (and in Germany in particular, where far more has been done than anywhere else for technical education and scientific research in Forestry), the main text has been largely amplified by Continental Notes in smaller type. In some cases these merely serve the purpose of explaining or illustrating what is said in the paragraphs immediately preceding them, while in others they contain additional information that a student of Forestry may naturally wish to know, and which may often suggest useful ideas for practical work in Britain. Where special use has thus been made of French, Austrian, and German works, suitable acknowledgment is given.

To illustrate the present new text, some of the original figures have again been used, together with all of those obtained, through the kind courtesy of German publishers, for the sixth edition of the old *Forester* in 1894. But numerous fresh illustrations have likewise been added from *Les Forêts*, by MM. Boppe and Jolyet, 1901, the *Trans. of the High. and Agri. Socy. of Scot.*, the *Trans. of the Royal Scot. Arbor. Socy.*, the *Journal of the Royal Agri. Socy. of Engl.*, the *Journal of the Board of Agriculture and Fisheries*, and Messrs A. Ransome & Co.'s *Catalogue of Wood-working Machinery*, and also by reproductions from recent photographs kindly placed at my disposal by the Earl of Mansfield, Mr Richardson Carr, Mr A. Allsebrook, F.S.I., and Mr A. D. Richardson; and I desire to record here my thanks to all of the above for the assistance thus rendered. I have also to thank Prof. A. S. MacDougall and Dr A. Borthwick, the Hony. Scientists to the Royal Scottish Arbor. Socy., for the help kindly given in revising the proof-sheets of chapters iv. and v. of Part IV., dealing with Injurious Insects and Fungous Diseases; Mr A. E. Wild, formerly Conservator of Forests, Bengal, for similar assistance with Part V.; and Messrs Robert Anderson, F.S.I., and D. F. Mackenzie, F.S.I., for help with portions of Part VI.

In the *Introduction* (p. 90) I have adverted to incorrect conclusions having apparently been drawn by the Departmental Committee on Forestry, 1902, from evidence that was incomplete, and therefore misleading. As the point at issue is important, I have made special inquiries into the subject, and the result of these may be condensed as follows:—

Anthonsthal and other ten neighbouring forests (or units of management, *Revier*) form a great and more or less compact mass of woodlands that are the main, and practically the only, sources from which can be supplied the requirements in raw material for 27 sawmills, 15 wood-pulp and cellulose factories, 26 pit-timber and building-wood businesses, and 20 cooperage-works,—apart from the local demands for wood-fuel. These industries are dependent on those woodlands, and could never have become established without them. These eleven forests have a practical monopoly in the supply of all the local wants, because no other timber is obtainable except from a long distance (involving a heavy charge for carriage), or else from Bohemia, the frontier of which is about 3¾ miles from the end of the Anthonsthal forest. But in the latter case there is, besides the extra cost of transport, a small *import duty* of 1s. 2½d. per cb. metre (35 cb. ft.)

This practical monopoly of itself ensures obtaining the highest market-value for the timber sold; and the receipts are still further increased through the care and skill employed in growing the kind of wood in demand (chiefly Spruce), and, more particularly, in bringing it to the market in the sorts, sizes, and condition best suited for the different industrial requirements.

The exceptionally profitable results at Anthonsthal and the adjoining forests are therefore mainly due to (1) a highly absorptive market in the immediate vicinity, with good competition; (2) careful preparation of timber to suit the market; and (3), but to a minor extent only, *protection* by means of an import duty levied on wood brought from Bohemia into Saxony.

Since the *Introduction* was printed, over a year ago, the Secretary of State for India has arranged for the transfer of the Forestry teaching staff from Cooper's Hill (see pp. 34 and 40) to Oxford University, and this technical course is to be followed by one year's practical training on the Continent. This new system is only to be on its trial for three years from 1st October 1905, before the end of which time he has promised to reconsider his orders so as perhaps to enable the Universities of Cambridge and Edinburgh to also provide instruction for those who have become probationers for the Indian Forest Service. In view of the prospect thus held out to other Universities, as in the case of probationers for the Indian Civil Service, and also in view of the urgent need that exists for the mother-country supplying trained foresters for her colonies and dependencies (and thus removing the national reproach of our having again, *quite recently*, been forced to engage German foresters to fill appointments in our British Colonies), it seems desirable that Forestry should be taught as a special branch in all of our Universities having an Agricultural Department, and that Chairs should also be endowed at the Royal Colleges of Science in London and Dublin. These latter would be of special benefit to the probationers for, and the junior members of, the Surveyors' Institution, which represents the bulk of the land-agency profession in the United Kingdom. What such a course should be, for British and Colonial requirements, is indicated on pp. 64-66 of the *Introduction*; but, for it to be really satisfactory, the lecture-room instruction should be combined with short tours to the best English and Scottish woodlands, and with a more extensive tour in France and Germany, to exhibit the methodical management of woodlands on a large scale.

Nearly two years have been devoted by me to the preparation of this book; and I hope that it may prove beneficial to British Forestry and Arboriculture, and helpful to those specially interested in the study of these branches of our Rural Economy.

J. NISBET.

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CONTENTS OF THE FIRST VOLUME.

PART I.—INTRODUCTION.

CHAPTER I.

BRIEF HISTORICAL SKETCH OF FORESTRY AND ARBORICULTURE IN BRITAIN.

CHAPTER II.

CONCERNING THE PRESENT EXTENT AND CONDITION OF THE WOODLANDS, AND OF TECHNICAL EDUCATION IN FORESTRY, THROUGHOUT GREAT BRITAIN AND IRELAND.

CHAPTER III.

THE CLIMATIC AND PHYSICAL INFLUENCE AND THE NATIONAL-ECONOMIC IMPORTANCE OF WOODLANDS.

PART II.—THE BRITISH SYLVA—OUR WOODLAND AND ORNAMENTAL TREES.

CHAPTER I.

CONCERNING BROAD-LEAVED TREES.

CHAPTER II.

CONCERNING CONIFEROUS OR NEEDLE-LEAVED TREES.

PART III.—SYLVICULTURE; OR THE FORMATION, TENDING, AND RENEWAL OF WOODLAND CROPS.

CHAPTER I.

THE SCIENTIFIC FOUNDATIONS OF SYLVICULTURE.

The Physiology of Forest-Trees, the Fundamental Facts of Agricultural Chemistry, and the Physical Properties of Soil.

CHAPTER II.

THE SYLVICULTURAL CHARACTERISTICS OF BRITISH TIMBER-TREES, AND THE DIFFERENT CLASSES OF WOODLAND CROPS: COPPICE, COPSE WITH STANDARDS, AND HIGHWOOD.

CHAPTER III.

SOWING, NURSERY WORK, AND PLANTING.

CHAPTER IV.

THE PLANTING OF WOODLANDS.

CHAPTER V.

THE TENDING OF WOODS AND PLANTATIONS.

Weeding and Cleaning, Thinning, Pruning, and Partial Clearance to stimulate Increment.

CHAPTER VI.

THE RENEWAL OF WOODLAND CROPS.

Reproduction of Coppices and Copse-woods, and Regeneration of Highwoods.

CHAPTER VII.

CONCERNING ARBORICULTURE,

Or Planting for Ornament and Shelter.

LIST OF ILLUSTRATIONS TO VOLUME I.

PART I.

INTRODUCTION

CHAPTER I.

BRIEF HISTORICAL SKETCH OF FORESTRY AND ARBORICULTURE IN BRITAIN.

Forestry or **Sylviculture** may be called the younger sister and the servant of **Agriculture**. Each of these arts is essential to the welfare of nations, and no people can be said to be wise, politic, or economic which does not pay attention to the advancement of both. In no other art or science has the Anglo-Saxon race displayed such indifference and neglect as with regard to Forestry. Even the term **Sylviculture** is not commonly found either in Dictionaries of the English language or in glossaries of technical and scientific terms; and little or nothing is known generally about this art, although Britain owns the largest and the most valuable woodlands in the world.

Primeval Woodlands.—Over by far the greater portion of the inhabited land of the globe, the clearance of natural woodlands, and not the cultivation of trees, has occupied the attention of man from the earliest ages. As long ago as the days of King David the Psalmist, "*A man was famous according as he had lifted up axes upon the thick trees.*" For thousands of years the same sort of work has been going on that is to-day being carried out in clearing remote jungles in Further India and elsewhere by dark-skinned nomadic tribes, and by white colonists throughout America, Africa, Australia, and other colonies. In tropical and subtropical districts this destruction of the natural forests for temporary agricultural occupation is usually soon repaired to a certain extent by nature; but where the occupation is permanent, even in tropical countries the wooded area ultimately becomes restricted only to parts having a soil too poor for permanent utilisation. In parts cleared by white settlers, on the other hand, the first clearance is generally made with the express intention of a permanent occupation.

The lands first cleared and permanently occupied are those offering natural advantages of some sort. Richness of soil, convenient situation on a large stream or at a ford facilitating communication, a locality easily defensible against enemies or floods, &c., are all matters that have always received, and still receive, more or less consideration in clearing away virgin woodlands; and when, in course of time, the clearance of the natural forests has given place to fields and pasturage, the only woodlands left are those either on poor stretches of land or in inaccessible tracts.

Gradually this destructive work has proceeded so far in certain countries that legislation has been required to protect the still existing wooded areas against further clearance; for it has been found that, except under unusually favourable conditions, the wastage of the natural forests has a very important influence on the off-flow of aqueous precipitations, on the movement of soil-moisture, and on the amelioration of any climate apt to vary from extreme heat in summer to intense cold in winter.

The Romans were the greatest of all the ancient nations with regard to Arboriculture. At an early period of their history they experienced the evil effects of the injudicious and excessive clearance of woodlands in the insalubrity of swampy tracts, and in the reaction on the productivity of agricultural lands. They were the first to introduce exotic trees into Britain. To them we owe the English Elm, the Sweet-Chestnut, the Lime, and the Poplar, together with other trees that failed to acclimatise themselves, and had to be reintroduced later on.

In considering the **History of Forestry in Britain** for the purpose of understanding its origin and development, and of noting how it gradually changed from game-protection in the earliest times to a combination of game-keeping and timber-growing, then mainly to Oak production for ship-building, and then (after the introduction of iron ships and of steam communication by land and water) back again chiefly to game-protection and ornamentation of estates, it seems most convenient to divide it into three Periods, namely:—

First Period, *from the Earliest Times to the Passing of the Statute of Enclosure in* 1482.

Second Period, *from* 1482 *to about* 1850, *when railway and steamship communications were fairly well developed.*

Third Period, *from about* 1850 *till now.*

To obtain a clear idea of the historic development of Arboriculture, it is only necessary to study the English forests. It was not until the sixteenth century that any sort of forest law was introduced into Scotland, and then the system was based on that obtaining in England; while in Ireland, where there were never any Crown forests, the first application of any Act was in 1634 (Charles I.)

FIRST PERIOD.—From the Earliest Times to the Passing of the Statute of Enclosure in 1482.

There can be no doubt that very extensive clearance of the primeval British woodlands took place at an early date, especially in the eastern and the milder central and southern parts of England, which were the first to be at all thickly populated.

The chalk-hills forming the backbone of the southern counties were probably mainly covered with Beechwoods, of which the patches still existing are but the poor scattered remnants. When the earliest tribes—at first nomadic, then permanent—settled near the watercourses, they probably subsisted mainly on roots and wild fruits, then were hunters and herdsmen before becoming agriculturists. Swine probably formed their first, and for long their only, possessions in the way of domestic animals, the herds being driven into the woods to feed on the Beech-mast and acorns.

Of what these lower woodlands must once have been we can form some idea from the fossils of the submerged forests fringing our southern coast. These show that the chief trees were Oak, Beech, Birch, Pine, and Hazel, while the wild animals comprised the urus, red-deer, roe-deer, wild boar, and short-horned ox. The Pine subsequently disappeared from the woodlands of Southern England,—whether through fires, or injurious insects, or fungous diseases it is impossible to say,—and was only reintroduced in 1776. This is the more curious as Pine now forms one of the characteristic features of Southern English scenery, being one of the few kinds of trees suitable for sandy and gravelly soil. After the introduction of fire, and of improvements in primitive implements, the clearance of the hill woodlands no doubt became more rapid, and the woodlands on the plains were also cleared.

During the four centuries of Roman occupation the Britons learned something of the Roman methods of agriculture, while the Germanic invaders (Saxons, Angles, Jutes, and Frisians) were still mainly dependent on flocks and herds fed in the woodlands. But as husbandry gradually grew in importance under later Saxon rule, enclosure of land became necessary to protect crops against wild animals. Further clearance of woodlands took place for cultivation, and enclosures were formed to keep out the deer, &c., and confine them as much as possible to the wooded tracts. Used first of all in the early times as common hunting-grounds, and furnishing a good deal of the food of the people, those wooded tracts gradually became sanctuaries for all animals of the chase. Eventually the more powerful landowners appear to have usurped the right of hunting deer and wild cattle, which formed the "higher chase," while the "lower chase" after minor kinds of game could still be followed by the common folk.

And later on, after kings had been elected, the Saxon kings seem to have claimed the overlordship of the higher chase within special tracts selected from among such woodland sanctuaries for game; and thus "royal hunting-grounds" were formed, afterwards known as the "king's woods" (*silva regis*) and then in part transformed into the "king's land" (*terra regis*). Without any exact history being traceable, it is only known that on Egbert becoming first king of all England, in 827, he was lord of many such "royal hunting-grounds" or "royal woods" throughout different parts of his kingdom. It is also probable that throughout the West Saxon and Danish reigns, although the higher chase after deer and wild cattle was reserved to the king in the "royal hunting-grounds," yet the freeholders of lands included therein could (down to the time of the Norman Conquest) follow the lower chase there, and might exercise the higher chase on their own lands not included within the tracts placed under reservation.

The laws of King Ine (between 690 and 693 A.D.), the earliest extant specimen of West Saxon legislation, show the importance of the woodlands for pannage of swine. Penalties were therein imposed on the burning of trees lest the woods should be destroyed, and the value of a tree was estimated according to the number of swine that could find shelter under it. Definite laws relating to hunting and woodlands were in force subsequently during the Saxon and Danish periods, but only untenanted tracts appear to have been placed under ban as "royal hunting-grounds."

Nothing is definitely known regarding the status of these "king's woods" immediately prior to the Norman Conquest. The *Saxon Chronicle* relates that the Conqueror "made many *deor-frið*, and laid down laws for them." This term *deor-frið* may mean either an "inclosure for deer" or a "sanctuary for deer"—or else, perhaps, comprehensively meant a "deer-park" in both of these senses.[1] If the Norman forgeries—the fictitious forest laws of Canute (1018)—can be taken to give any fair idea of the legal status of the *deor-frið* existing before the Conquest, then it would seem that every freeman might hunt on his own lands, but was forbidden under penalty from hunting over the chases of the king; and apparently each royal hunting-ground was in charge of four thegns of high degree (*ealdermen*) and four minor thegns (*lesthegend* or *jungmen*), assisted by huntsmen and keepers (*tinemen*). These were, of course, all Englishmen, and after the Conquest they passed into the service of William I., as is shown, *e.g.*, by reference to "Waleran the huntsman," "Ulviet the huntsman," and "Herbert the forester" in the Hants Domesday. And in the Gloucester Domesday William, the son of Norman, is entered as holding land in Dean [forest], and "King Edward [the Confessor] granted these lands, tax free, for keeping the forest."

Origin of term "Forest."—When William I. took possession of all the royal estates by right of conquest, he of course assumed full rights in all the *deor-frið* or royal hunting-grounds. But the game laws he found in force,

[1] It is popularly supposed, owing to the statement made to that effect in a note at the end of Sir Walter Scott's novel, that Woodstock was the first "park" in England. This is quite a mistake, because Domesday-Book contains specific mention of parks—*e.g.*, the entry in the Surrey Domesday regarding the king's demesne land in Stochæ (Stoke, Guildford), which was said to contain "a wood of 40 hogs, and the same is in the King's park" (*Silva xl. porcorum, et ipsa est in parco regis*).

Sir Walter Scott, a great admirer of Evelyn's *Sylva*, probably accepted this statement on Evelyn's authority. Apparently made from memory and never verified by examination of the work referred to, this statement in question mentioned (see Hunter's edition, 1786, vol. ii. p. 278) "Woodstock (which, as Camden tells us, was the first park in England)." But Camden really said something quite different: "*Henry* the first also adjoin'd to the Palace [of Woodstock] a large Park enclos'd with a wall of Stone; which John Rous affirms to have been the first Park in England, though we meet with these words, *Parca sylvestris bestiarum*, more than once in Domesday-book. But afterwards they encreas'd to so great a number that there were computed more in England than in all the Christian world besides; as great delight did our Ancestors take in this noble sport of Hunting" (Camden's *Britannia*, 2nd edit., 1722, p. 298).

or the habits and customs having by long usage the effect of laws—which inflicted fines only—were nothing like so stringent as he intended they should henceforth be. He desired to establish his supreme dominion over the chase, and at the same time to weaken the power of the landowners. He therefore resolved to enlarge the boundaries of various *deor-frið* in different counties by including extensive areas of cultivated and uncultivated lands, to place all under ban as sanctuaries for game (and especially for deer), and to reserve to himself the sole right of hunting there, or of conferring the privilege of the chase upon favoured nobles.

All the land thus laid under ban in each case—whether consisting of woodlands, barren moor, fields, or pastures—was known, from the time of the Domesday Survey (1081 - 1086) onwards, as a *foresta*, a Norman-latinised form of the old German *Forst* (in use since the ninth century, under the German emperors), which later became anglicised as "forest"; while the placing of such tracts under ban became subsequently known as "afforestation."

The first afforestations made by the Conqueror were merely extensions of the boundaries of previously existing *deor-frið*, and they were simply made by order of the king, as is evident from the entry in the Gloucester Domesday relating to the land of William de Ow, on the river Wye, "It is now by the king's command in his forest" (of Dean), formed at some time between 1066 and 1086. The *foresta*, a forest in its earliest sense, as well as in its medieval and legal application, was not necessarily a woodland, nor was any woodland necessarily a forest; but each forest usually contained a greater or less extent of woodlands to provide cover and quiet for the deer and other game. It had at first nothing whatever to do with the growth of timber.[1]

The "forests" formed by the Conqueror were extensions and transformations, not new creations. Whole manors and villages were sometimes included, in place of only parts as formerly; new and savage laws were applied to the forest administration, and stringently enforced. To what extent William I. made afforestations can never be known exactly, but the great Domesday-Book (1081-1086) mentions at least six forests—New (Hants), Dean (Gloucester), Windsor (Berks), Huchennode (Whichwood, Oxford), Winburne (Wimborne, Dorset), and Gravelinges (Wilts).

In carrying out his intentions, William I. paid little regard to the feelings of the landowners and peasants whose lands were included within his

[1] The most comprehensive definition of the word **Forest**, as now understood, would be something like the following: Originally a tract of land reserved for the king's hunting (1066-1086), and subsequently including all land whatsoever within forest limits administered (down to 1640 virtually, and to 1817 legally) under forest law, and not (like all other land) under English common law. The term is now laxly applied to all woodlands and to open waste where deer-stalking is practised (a deer-*forest* being precisely similar to a grouse-*moor*, except as regards the particular kind of sport indulged in).

It may be noted that all the Indian Forest Acts and Rules (passed since 1878) purposely avoid the definition of the word "forest," although very precise in defining every other term used.

"forests"; but the accounts of Henry of Huntingdon (soon after 1135) and other monkish historians, as to his causing churches and villages to be destroyed, and driving out the people to form the New Forest, are without the slightest doubt gross exaggerations. The land was (and still is) poor and barren; and even in Edward the Confessor's time it was assessed at a very low valuation compared with other parts of the country, while the valuation sank very little after the afforestation, and in some cases compensation was even given by reducing the assessment owing to the loss of the right to use the woodlands (*e.g.*, as in Bernard Pancevolt's land in Mansbrige hundred).

It is possible that the already-mentioned forged laws of Canute, written in the Danish language, and supposed to date from 1018, were concocted during the reign of the Conqueror in order to effect by subterfuge his feudal and political ends regarding afforestation; but the opinion of historians seems to consider it as most likely to belong to the reign of Henry I.[1]

Under William II. the afforestations were extended in many parts of the kingdom, and he made the forest laws still more savage than they had been. Whereas the Saxons and Danes merely exacted fines as penalties, the Conqueror punished offences with mutilation; but William Rufus often exacted the death penalty from Englishmen and Normans, peasants and nobles. The rural population and the barons groaned under this tyranny. When he was in serious trouble with his Norman barons and prelates, he promised to grant to men "their woods and liberties of the chase; but it stood nowhile" (*Anglo-Saxon Chronicle*, folio 357). His tragic death in the New Forest was deemed only a fit end to a cruel career marked by savage enforcement of the forest laws.

Henry I. had to relax these harsh laws on coming to the throne, but later on he showed the same cruel tendencies as his father and grandfather. When his nephew Stephen usurped the throne, he was anxious to conciliate the nobles and people, and was full of concessions, which he also failed to keep. During these two unsettled reigns, many encroachments were made in the king's forests, and Stephen was compelled to disafforest the forests made by Henry I., while retaining those of William I. and II.; but during the reign of Henry II. large new afforestations were made throughout England, and the forest laws were recast.

In the statute known as the *Assize of Woodstock*, 1184, the first genuine code of forest laws was enacted having general application throughout the realm, and the forest law was then placed upon a distinct and definite footing independent of the common law. It was an arbitrary code, but it provided a definite administration by giving a separate jurisdiction to "Justices in Eyre," who held the forest courts attended by all men summoned thereto by the Master Forester; but Richard I. compelled the whole population to attend the forest courts. Although these new forest laws substituted fines instead of death or the barbarous mutilations of hands, feet, and eyes, yet

[1] Freeman, *The Norman Conquest*, vol. v. p. 456; Stubbs, *Constitutional History*, 6th edit., vol. i. p. 220.

they were still very stringent and oppressive. A landowner could cut nothing but fuel in his own woods, and that only in the view of the king's forester; while the clergy, though exempt from common law, were made subject to forest law. But for Richard I.'s prolonged absence on crusades, his reign would also have been marked by very harsh administration of the forest laws, for he had the Norman passion of hunting.

Under King John afforestations again became so extensive, and the administration of the forest laws so stringent, that when *Magna Charta* was wrung from him in 1215, sections 44, 47, 48, and 53 contained clauses relating specially to the forests, and relieving the people from some of the most oppressive of the forest laws. And after granting them, he tried to evade them; but as he died in 1216 and was succeeded by the boy-king Henry III., the Earl of Pembroke being regent, things were soon put in train for a more satisfactory settlement of the many grievances felt with regard to the royal forests.

In 1217 a Forest Charter was issued abolishing some of the worst abuses. It decreed that all afforestations made "of any other wood than his own demesne" by Henry II. should be disafforested; and in 1218 a *pourallée* or "perambulation" was held to fix the true boundaries of forests made previous to 1154.

After these perambulations had been made and recorded, a new Forest Charter was enacted in 1225, about two years before the king's majority, in which all lands afforested by Henry I. or Richard were declared to be disafforested, except demesne woods of the Crown, while afforestations of Henry II. were also to be disafforested wherever they caused damage to the owners of the woods. Fines were again substituted for heavier punishments, and this statute and *Magna Charta* are the two great enactments which preserved the lives and liberties of the people then and for long after.[1] It is now hardly possible to realise what this charter meant to the rural population. A freeman might do acts previously forbidden "in his own wood"; he could even, for example, "have also the Honey that is found within his Woods." But it was doubtless section 10 which gave the greatest relief from the cruel severity of the laws and the brutality of

[1] Its sixteen sections dealt with the following matters:—

(1) Certain Grounds shall be disafforested. (2) Who are bound to the Summons of the Forest. (3) Certain Woods made Forest shall be disafforested. (4) No Purpresture (or enclosure), Waste (or clearance), or Assart (or stubbing up roots), shall be made in Forests. (5) When Rangers shall make their Range in the Forest. (6) Lawing of Dogs in Forests. (7) In what only Cases Gatherings (*i.e.*, collections of oats, corn, lambs, pigs, &c.) shall be made in Forests, and the Appointment of Foresters. (8) Where Swainmotes (and other Forest Courts) shall be kept, and who shall repair to them. (9) Who may take Agestment (or fees for the grazing of cattle in the royal forests) and Pawnage (*i.e.*, the "pawnes" or money taken for the pannage of swine in the royal woods) in Forests. (10) The Punishment for killing the King's Deer. (11) A Nobleman (spiritual or lay) may kill a Deer in the Forest; but this was only if "coming to us at our commandment." (12) and (13) How a Freeman may use his Land in the Forest. (14) Who may take Chiminage or Toll in a Forest, for what cause, and how much. (15) A Pardon of Outlaws of Trespass within the Forest. (16) How Plea of the Forest shall be holden.

forest officials in extorting money from offenders or those charged with alleged offences :—

No man from henceforth shall lose either Life or Member for killing of our Deer: (2) But if any man be taken and convict for taking of our Venison, he shall make a grievous Fine, if he have anything whereof: (3) and if he have nothing to lose, he shall be imprisoned a Year and a Day: (4) and after the Year and Day expired, if he can find sufficient sureties, he shall be delivered; and if not, he shall abjure the Realm of England.

But the provisions of such charters seem to have been adhered to only so long as the king felt himself unable to neglect them. Soon Edward I. began to reafforest in various counties, and the barons had again to interfere and force him to confirm the Great and the Forest Charters in 1299, when a second *pourallée* or general perambulation of the forests was held in order to inquire into and rectify the infringements of the *Charta Forestæ* of 1225. This Perambulation Roll (29 E. I.) gives a list of all the forests then in England. He had again to confirm these in section 1 of the twenty *Articuli super Chartas* of 1300, when he was in straits for money wherewith to prosecute his French war. In 1305 he obtained a papal bull absolving him from these oaths; but the barons took a firm stand, and caused an *Ordinatio Forestæ* to be passed in 1306 amending and regulating the procedure in presenting, trying, and punishing forest offences, and determining that "They whose Woods are disafforested, shall not have Common or other Easement in the Forest." This statute of 1306 ordained that alleged offences against vert (*e.g.*, greenhew or cutting timber, &c.) or venison should be presented at the next swainmote, and there tried in presence of the foresters, verderers, and other ministers of the forest. It secured something like the right of trial by jury, because the verderers (who were now to form a part of the bench) were to be chosen by the local freeholders and then appointed by writ of the king.[1]

After Edward I.'s death in 1307 matters seem to have improved a little, because no fresh forest legislation was enacted in Edward II.'s reign. But when Edward III. ascended the throne in 1327 the forests were ordered to be perambulated as in the time of Edward I., the portion of the enactment dealing with forests being as follows :—

Cap. i.—First, That the Great Charter of the Liberties and the Charter of the Forest be observed and kept in every Article; (2) And that the Perambulations of the Forest in time of King Edward, Grandfather to the King that now is, be from henceforth holden in the like Form as it was then ridden and bounded; (3) and thereupon a Charter to be

[1] In six short sections it managed to give a good deal of relief to the rural population, though their burden was still grievous :—

(1) How Offences done in the Forest shall be presented; (2) An Officer dying, or being absent, another shall be put in his Place; (3) No Forester shall be put in Assizes or Juries out of the Forest; (4) The Punishment of Officers surcharging the Forest; (5) Grounds disafforested; (6) Common in the Forest.

Malpractices were common; the number of foresters was often excessive; and, poorly paid, they habitually extorted money by trumping up false charges, as well as by illicit traffic in vert and venison.

made to every Shire where it was ridden and bounded. (4) And in such Places where it was not bounded, the King will that it shall be bounded by good men and lawful, and that a Charter be thereupon made as afore is said.

Cap. ii.—Every Man that hath any Wood within the Forest may take Houseboot [*i.e.*, timber for repairs to houses and tenements] and Heyboot [*i.e.*, brushwood for hedges and fencing] in his said Wood, without being attached for the same by any Ministers of the Forest, so that he do the same by the view of the Foresters.

Again and again (fifteen times in all) such confirmation of *Magna Charta* and the *Charta Forestæ* formed chapter i. of Statutes passed by new Parliaments between 1328 and 1377; but the statute of 1327 gave relief from oppression and vexatious interference with the rights of those owning or holding land in or near a royal forest. That extortion was rife, however, seems clear from sections 6 and 7 of the *Statute of Purveyors* (1350) enacting that "A Purveyor (for the navy) shall not take Timber in or about any Person's House," and that "Keepers of a Forest or Chase shall gather nothing without the Owner's Good Will." And again, in 1383 (Richard II.), it was enacted that "A Jury for a Trespass within the Forest shall give their Verdict where they received their Charge," and that "None shall be taken or imprisoned by the Officers of the Forest without Indictment."

The forest laws had become more or less crystallised by this time. Though every now and again the reigning king tried to break through the restraints placed upon him and to increase the boundaries of the royal forests, yet there was no great or sweeping change in the forest laws till 1640, when their application was virtually cancelled, as finally took place in legal form in 1817.[1] From about the end of the eleventh century onwards the king, whenever he desired to afforest certain lands (perhaps only partially wooded), appointed a commissioner under the great seal to view, perambulate, and bound them; and after the record had been certified and returned to Chancery, the sheriff of the county was ordered to proclaim the "afforestation" of the tracts, and to prohibit the hunting of any wild beast without special licence from the king. This constituted it a "chase" (*chaseus*) or sanctuary for wild animals. But it was not a "forest" (*foresta*) until certain forest officers were appointed, when it became subject to forest law only, to the jurisdiction of the forest courts as distinct from the courts of common law, and to the administration of the forest officers. These officers could only be appointed by and act for the king, hence no subject could own a forest unless by a special Act of Parliament, as in the case of the *Grant of the Forest of Dean, as a Forest, to the Duke of Gloucester* in 1390 (Richard II.) If the king granted any forest (or portion of a forest) to a favoured subject, the tract granted at once ceased to be a forest, reverted to the status of a chase, and again became subject to common law. The minor executive officers might indeed remain, when, as Manwood points out, they ceased to be "foresters," and were called

[1] The most complete record yet published concerning the forests and forest courts during the thirteenth century is contained in the *Select Pleas of the Forest*, edited by G. J. Turner for the Selden Society (vol. xiii., 1899: London, 1901). Further details than are here given will also be found in the article on *Forestry and the New Forest* in vol. ii. of the *Victoria County History of Hampshire* (1903).

"keepers";[1] but the justice in eyre, the highest official of all, and one whose appointment was essential to a forest, could only act as a commissioner for the king. A chase was (like a forest) a large unenclosed tract, forming a sanctuary for all kinds of game, though the animals proper to it were the buck, doe, marten, and roe. Lower in degree than a chase came a "park" (*parcus*). This was a sanctuary for the animals proper to a chase, but it was usually much smaller in area, and had invariably to be "imparked" or fenced in with stout oak paling to prevent the fallow and roe deer from straying beyond its boundaries. If proper fences were not erected or maintained, the king could afforest the land as if it were a "free chase." The lowest kind of game preserve was the "warren" (*warrenus*), the animals proper to which were the hare, rabbit, pheasant, and partridge.

The officers appointed for the administration of each forest consisted of the justice in eyre, verderers and their steward, regarders, foresters, agistors, and woodwards, though there were often also a warden or master forester and minor local officials.

The justice in eyre (*justiciarius itinerans*), the highest of all the forest officers, was usually a nobleman of high rank, who held a roving commission for the administration of the forest laws and the keeping of the Justice Seat or High Court of the Forest in the course of his circuits. Originally there were three justices in eyre, but after 1225 only two were commissioned, whose respective provinces lay to the north and the south of the river Trent. Till 1540 (Henry VIII.), when a special Act enabled them to appoint deputies, they had to perform the duties of their high office *in propriâ personâ*. But in 1640 the office was virtually suspended by circuits being put an end to by the *Act of Limitation*, though it was not till 1817 that the office was formally abolished by Act of Parliament, when the performance of the duties was vested in the First Commissioner of Woods and Forests.[2]

The verderers (*viridarii*) were judicial officers appointed by royal writ from among the neighbouring landowners. There were usually four for each forest—just as there used to be four chief thegns in Saxon and Danish times. They had to keep the assize of the forest, and to receive, view, and enrol all presentments and attachments regarding offences against the forest laws. They were the judges in the Swainmote, where they were assisted by a steward (*senescallus*) learned in the law, and they gave directions to the other forest officers.

The regarders (*regardatores*) were charged with supervising the general work of the local executive officers. For each forest twelve regarders were appointed, either by letters patent or else by the justice in eyre, when a "regard" of the forest had to be made during every third year. At such times any vacancy in their number had to be filled up temporarily in the latter manner, because (like a jury under common law) they had to be unanimous in their verdict before they

[1] "A Chase hath no such Officers as a Forrest hath, for a Chase hath neyther Verderers, Forresters, Regarders, nor Agistors, but only Keepers, and Woodwardes. A Chase hath no Court of Attachments, Swainmote, nor Justice Seat, as a Forrest hath. And note, that these Officers which are called Keepers in a Chase, are called Forresters in a Forrest." (*Treatise of the Lawes of the Forrest*, fol. 7.)

[2] Charles II. tried to revive the forest courts, and Vere, Earl of Oxford, held circuit at Lyndhurst, in the New Forest, in 1669 and 1670. The coat of arms then used still hangs there. The last *iter* or circuit for the Forest of Dean was held at Gloucester in 1639.

could certify and enrol any presentment for trial at the next justice seat. They had, as their name implies, to look into all matters connected with the forest. They examined the fences, inspected all operations carried out in the forest, made inquiries regarding those who had bows and arrows, and saw that the inhumane law relating to the laming or "lawing" of dogs was carried out, as prescribed by law, on mastiffs owned by men residing within the forest.[1]

The foresters (*forestarii*) ranged the forest to protect the vert and venison, and made attachments and presentments in the case of offences. They were usually appointed under letters patent, but their number varied greatly. Being often appointed in unnecessarily large numbers, they then lived mainly by extortion, and special Acts had to be passed from time to time to try and protect the rural population from their oppression and rapacity. At a comparatively late date, when timber had become valuable, they were assisted in their work by woodwards (*woodwardii*), who performed miscellaneous duties with regard to vert, such as marking timber for sale, superintending the felling, &c.

In forests containing woodlands there were usually four agistors (*agistatores*), appointed by letters patent to collect the grazing dues or "agistments," to take charge of the herds of cattle and swine belonging to those having rights of common in the forest, to prevent trespass by cattle, and to present their accounts at the justice seat.

Forest Courts.—There were three distinct courts of the forest. The lowest of these was the *Woodmote*, *Court of Attachment*, or *Forty Day Court*, ordered by the Forest Charter (1225) to be held once every forty days, but often kept very irregularly, to the annoyance and oppression of the people. It was merely a court of preliminary inquiry, from which attachments could be presented to the Swainmote if the alleged offences seemed actually to have been committed, and were capable of being proved.

The *Swainmote* or *Court of Freeholders*, in which the verderers were the judges and twelve "swains" or freeholders of the forest formed the jury, tried all cases committed from the woodmote. Each town and village in the forest had to be represented by a reeve and four swains, from among whom the jury was chosen; and all freeholders were bound to serve when called upon to act as representative swains.

The Swainmote could order conviction and fine in all petty cases, but serious offences had to be committed to the next justice seat. And as it was merely a court of trial, and not of record, its convictions had to be certified under the seals of the jury, and presented to the justice seat for confirmation by the justice in eyre and for execution thereafter. It was ordered by law to be held thrice a-year, the stated times being fifteen days before Midsummer, fifteen days before Michaelmas, and forty days after Michaelmas, when orders were respectively issued regarding (1) the fawning season or "fence month" for the deer, (2) the opening of the forest to cattle and swine, and (3) their subsequent removal, in order to reserve the woods for the deer during the "winter haining," lasting from late autumn till the next spring.

The *Justice Seat* or *Eyre of the Forest* was the High Court for the administration of the forest laws. It was ordered by law to be held in each forest once every third year, but originally it had been held at irregular intervals upon a general

[1] The so-called "Stirrup of Rufus," seen by visitors to the Verderers' Hall at the King's House, Lyndhurst, has for ages hung there as the ancient gauge of the dogs allowed to be kept in the forest without expeditation, the "lawing" or mutilation of the claws and ball of the forefeet being carried out on all "great dogs" that could not pass through the stirrup. From its appearance, however, it seems highly improbable that the stirrup can be so old as tradition says.

"summons of the forest" being issued to all the men resident in the county. At the justice seat all inhabitants of the forest had to take the oath of allegiance to the king on their attaining the age of twelve years. Here the justice in eyre confirmed the convictions entered by the swainmote and entered judgment for execution, passed orders on petitions presented and on other matters connected with the administration of the forest. Assisted by a jury of eighteen, twenty, or twenty-four men selected from among the assembled freeholders, he tried all cases presented by the swainmote and gave decisions, which could only be revised or amended on a writ of error into the King's Bench at Westminster.

The acts or omissions constituting offences against the forest laws were excessive in number, but only those which concerned the woodlands are of interest here. The forests were lands (not necessarily woodlands) reserved for royal hunting, and they consisted of "vert and venison." The first included all trees, coppices, and turf forming the coverts and feeding-grounds of the deer and other game, while the latter comprised all kinds of wild animals, though the "beasts of venery" proper to the forest were the hart, hind, wild boar, wolf, and in some cases the hare.[1] The three greatest offences against "vert" were *Purpresture* or trespass and enclosure, *Waste* or clearance of cover, and *Assart* or digging up roots to transform woodlands into fields for ploughing or pasturage. Any enclosure of land within the limits of a forest, without previously obtaining permission, was an encroachment, and punishable as "purpresture." If any freeholder, without first of all obtaining the royal permission or a special licence from the justice in eyre, felled timber within his own woods or ploughed one of his own meadows, he was guilty of "waste," and the land could be seized for the king's use till a fine had been paid for committing such offence. If any part of a woodland or other cover were grubbed or pulled up by the roots, this was an "assart," and it was a graver offence than either of the other two, because it completely destroyed the land as cover for game. Permission to assart could be obtained by royal favour. Noblemen in favour with the king could also obtain special licence, on the eve of a triennial regard of the forest, absolving them from fines and penalties to which they might else be subjected for any purpresture, wastes, or assarts discovered on their lands. But charges respecting trespasses frequently opened the door to grievous extortion, and the Pipe Rolls sometimes showed a whole county entered as "*in misericordia pro foresta.*"

After the death of Edward III. no important legislation was effected regarding the forests for over a century. There were casual statutes for specific forests in various counties — *e.g.*, as in 1429, when an Act had to be passed giving a remedy to the inhabitants of Tewkesbury, owing to the Forest of Dean then being infested by a band of robbers, who ravaged the countryside and terrorised the Severn Valley.

[1] Precisely what were "the beasts of the forest" seems to have depended partly on time and place. The wolf was no doubt the first to disappear, and then, long afterwards, the wild boar. "It may be confidently asserted that there were in general four beasts of the forest, and four only,—the red-deer, the fallow-deer, the roe, and the wild boar,—the only exception being that in a few districts the hare was also made the subject of the forest laws."—*Select Pleas of the Forest* (Selden Society, vol. xiii., 1899), edited by J. G. Turner, M.A., 1901; Introduction, p. 13.

SECOND PERIOD.—From 1482 to about 1850.

When the country had recovered from the desolating effects of the Wars of the Roses, attention began to be paid to Arboriculture, a *Statute of Enclosure* being enacted in 1482, which marks the entry into the second period in the history of British Forestry. This short but very important Act passed in 1482 (Edward IV.) was entitled *An Act for enclosing of Woods in Forests, Chases, and Purlieus*—the "purlieus" being land that had been afforested and then subsequently disafforested after the necessary perambulation. This Act enabled landowners to enclose their lands against deer and cattle for seven years after each time of cutting the coppice, in place of only for three years, as seems to have been customary before then—"*to save the young Spring of their Woods so cut.*"[1] This first arboricultural Act in Britain consisted merely of the one section—

That if any of his Subjects, having Woods of his own growing in his own Ground, within any Forest, Chase, or Purlieu of the same, within this Realm of England, from the First Day of this Parliament, shall cut, or cause to be cut the same Wood, or Part thereof, by Licence of the King, or of his Heirs, in his Forests, Chases, or Purlieus, or without Licence in the Forest, Chase, or Purlieu of any other Person, to make any Sale of the same Wood; it shall be lawful to the same Subjects, Owners of the same Ground whereupon the Wood so cut did grow, and to such other Persons to whom such Wood shall happen to be sold, immediately after the Wood so cut, to cope and enclose the same Ground with sufficient Hedges, able to keep out all Manner of Beasts and Cattle forth of the same Ground, for the preserving of their young Spring; and the same Hedges so made, the said Subjects may keep them continually by the Space of Seven Years next after the same enclosing, and repair and sustain the same as often as shall need within the same Seven Years, without suing of any other Licence of Him, or of his Heirs, or other Persons, or any of their Officers of the same Forests, Chases, and Purlieus.[2]

Although no exact dates can now be fixed for the introduction of either *sowing* (then called "setting," and apparently the usual way of making "plantations"—by "planting" the seed—down to the end of the sixteenth century) or *planting* with live-plants according to the later meaning of this term, yet it is at any rate clear from the above Act that enclosure for pro-

[1] The preamble to the Act makes this clear: "Item, our said Lord the King, considering that divers subjects having woods growing in their own ground within the forest of Rockingham, and other forests and chases within his realm of England, or purlieus of the same, which have cut their said wood, because the same subjects might not before time cut nor enclose their said ground, to save the young spring of their wood so cut, any longer time than for three years, (2) the same young spring hath been in times past, and daily is destroyed with beasts and cattle of the same forest, chases, and purlieus, to the great hindrance, as well of his said subjects, as of his deer, vert, and venison in their covert, and otherwise likely to be the destruction of the same forests, chases, and purlieus," &c.

[2] Whether intentionally or unintentionally, this appears to have been the first time in which a subject is referred to as having a *forest*.

The very plain distinction between "forest" and "purlieu" appears to have been often intentionally overlooked by the kings and queens from Henry VII. to James I.; and Charles I.'s reassertions of illegal authority subsequently provoked the crisis which produced the Act of Limitations in 1640.

tection of stool-shoots and self-sown seedlings had long been customary before 1482.

It should be noted that this was purely a permissive Act, which applied only to the royal forests and chases and their purlieus. But the "wastage" or clearance of woods for agriculture, and the growing necessities of the country with regard to timber, were already beginning to render necessary compulsory measures regarding both the royal forests and the private woodlands; and this entirely new note was sounded about sixty years later, in 1543, when the *Statute of Woods* or *Act for the Preservation of Woods* was passed, of an entirely compulsory and prohibitive nature, and applying to all woods throughout the kingdom.

In this sixty years' interval, however, some miscellaneous Acts were passed affecting forests generally, in addition to those relating to particular individual forests. These included *An Act against unlawful Hunting in Forests and Parks* (1485, Henry VII.), by which those convicted of hunting "with painted faces, visors, or otherwise disguised, to the intent they should not be known, or of unlawful hunting in time of night," should be liable to the same penalty as for felony: and that was death. But in 1539 Henry VIII. went further, and made it felony "to take in the King's ground any egg or bird of any Faulcon, Goshawk, or Laner, out of the nest, . . . or to kill and steal any rabbits," &c. In 1540 this statute was extended to any "lawful Warren or Park"; but these two inhuman Acts were both repealed in 1549 (Edward VI.) In 1540 the *Drift of Forests*, or *An Act concerning the Breed of Horses of Higher Stature*, ordered that the forests, heaths, chases, commons, and waste grounds should be driven once a-year (on St Michael's day, or within fifteen days after it) for ascertaining that the forests were not burdened by too many horses and cattle owned by those possessing common rights, and for killing weakly mares and foals. And *An Act that Justices of the Forests may make Deputies*, for the more speedy accomplishment of "all things concerning the King's Forests, Parks, and Chases, and all other Things concerning the Office and Offices of the Justice of the Forests" (see p. 12 above), was also passed in 1540.

That the poorly wooded condition of England was even in the first part of the sixteenth century beginning to cause a feeling of national concern, is clear from Harrison's *Description of England* (in what is commonly known as Holinshed's *Chronicles of Britain*), where it is stated that in the reign of Henry VIII. "*plantations of trees began to be made for purposes of utility*," though "plantation" here probably only meant the sowing or "setting of acorns." In 1523 John Fitzherbert published his *Book of Husbandry*, which may be considered the first work referring to arboriculture.

In 1542 (November 28) an Exchequer record was issued by the Surveyor-General of Crown Woods to the Deputy-Surveyor of Hants, ordering him

Not only to Survey the King's said woods both great and small with their values and ages in every Lordship and Seignory within the said County and the wastes and sales in them made, &c., but also to make sale to the King's use at the best price you can before Easter next coming of as many Coppice Woods of 14 years' growth and upwards in the said County a Yearly Sale, Provided that in your Sale you suffer no Timber or great trees to be felled or sold Enclosing the same sufficiently at the King's charge for preservation of the spring for 6 years next after each such Sale—making returns of your proceedings in Easter and Midsummer terms next following, &c.

The preamble to the *Statute of Woods* of 1543 also expressed clearly the national concern :—

The King our Sovereign Lord perceiving and right well knowing the great decay of timber and woods universally within this his realm of England to be such, that unless speedy remedy in that behalf be provided, there is great and manifest likelihood of scarcity and lack as well of timber for building, making, repairing, and maintaining of houses and ships, and also for fewel and fire-wood, for the necessary relief of the whole commonalty of this his said realm.

The main provisions of its 21 sections (it was a long Act for those days) were :—

That in and upon all and singular several woods, commonly called coppice woods or underwoods, which from and after the feast of St Michael the archangel, which shall be in the year of our Lord God 1544, shall be felled at 24 years' growing or under, there shall be left standing and unfelled, for every acre of wood that shall be felled within the said coppice, 12 standils or storers of oak ; (3) and if there be not so many standils or storers of oak there, that then there shall be left so many of other kind, that is to say, of elm, ash, asp or beech, as shall make up the said number of 12 standils or storers, likely to prove and to be timber-trees ; (4) the same standils or storers to be of such standils or storers, as have been left there standing at any the felling of the same coppice woods or underwoods, in times past ; and in case there be no such standils or storers there standing, which were there left at the last felling of the same coppice or underwoods, then the same standils or storers there to be left, shall be left at this now next felling of the said coppice woods or underwoods, of such most likeliest oaks, and if there be not sufficient of oaks, then of the most likeliest elms, ash, asp or beech, to prove and to be timber-trees, as shall grow within any such several woods, coppice or underwoods ; (5) and that the same standils or storers so left, shall be preserved, and not felled or cut down, till they and every of them shall be of 10 inches square within 3 foot of the ground ; (6) upon pain that every owner of every such standils and storers having an estate of inheritance, or an estate for term of life of freehold, or by copy of court roll, or for years, in the ground or soil where the same standils or storers shall grow, causing or commanding any such coppice woods or underwoods to be felled or cut down, and not leaving the said standils or storers there standing in form aforesaid, to lose and forfeit for every standil and storer so not left standing in the said coppice woods or underwoods 3s. 4d. ; (7) and upon pain that every owner, as is aforesaid, of any such coppice woods or underwoods, causing or commanding any of the said standils or storers, so left as is abovesaid, to be cut down, contrary to the form of this act, to forfeit and lose for every of the said standils or storers which shall be so cut down, 3s. 4d. ; (8) the one half of which said forfeiture to be to the king our Sovereign Lord, and the other half to be to the party that will sue for the same in any court of record by action of debt, bill, plaint or information, in the which action, bill, plaint and information, no protection, wager of law nor essoin shall be admitted or allowed.

It also provided—

(1) For the enclosure and fencing for four years of coppices worked with a rotation of fourteen years or under, under a fine of 3s. 4d. per acre for every month during the four years "that the same coppice or underwoods shall happen to lie or be unclosed, not fenced, saved, or preserved" ; and (2) similarly, coppices worked with a rotation of between fourteen and twenty-four years were to be enclosed and fenced for six years, upon like penalty of 3s. 4d. per acre per mensem ; and (3) when woods or coppices having standards of over twenty-four years in age were felled or "weeded" (*i.e.*, thinned), then "for every acre so felled, twelve trees of oak of the same such great trees" (or, failing these, of elm, ash, asp or beech) were to be left standing for the next twenty years, and

the falls were to be enclosed and fenced for seven years, under penalty of 6s. 8d. per tree felled in excess of this statutory injunction, and of 3s. 4d. per acre per mensem for non-enclosure ; (4) no coppice woods of two acres or above in extent were to be converted, after Michaelmas 1544, into pasture or tillage, if distant two furlongs from the house of the owner or tenant thereof, under penalty of 40s. per acre thus transformed.

While this great compulsory Act was framed to prevent further "*wastage*" of woods, due provision was made for *bonâ fide* domestic and agricultural requirements :—

Provided always, that it shall be lawful to every owner or owners of any of the said coppice woods, underwoods, standils or storers, great woods and trees afore rehearsed, to fell, cut down and take any of the same for building, repairing, enclosing and maintaining of houses, orchards and gardens, and every of them, and for paling, railing or enclosing of parks, forests, chases or other grounds, and for making and repairing of waterworks, dampness, bridges, floodgates, making, repairing, or amending of ships and all other vessels, and for all such things concerning their own uses or affairs, in such like manner and form as he or they should or might lawfully have done before the making of this Act; anything in this present Act before mentioned to the contrary thereof notwithstanding.

It likewise provided, among other things, for fellings and enclosure in woods where commoners had rights of pasture, and ordered that swine "being of the age of ten weeks or above," taken to the woods for pannage, should be "sufficiently ringed or pegged," under a fine of fourpence for each swine.

In the first year of Queen Elizabeth's reign (1558), *An Act that Timber shall not be felled to make Coals for burning of Iron* was passed, which applied to any "Timber-tree or Timber-trees of Oak, Beech, or Ash" growing within fourteen miles of the sea or of any navigable river or stream. In 1570, the arboricultural provisions of the great *Statute of Woods* being already found inadequate, the Act was amended by increasing the time of enclosure for regeneration by two years in each case—"for that by experience it is found that the space and time of the said several years of enclosure or preservation is not sufficient."

Careful attention was for some time given to timber in the royal forests. In 1565 Roger Taverner, the queen's surveyor, drew up a *Book of Survey* concerning the acreage, description, and condition of all the forests south of the Trent, and about twenty years later John Taverner, his successor, made a similar survey (1584).

Some of the "encoppicements" or enclosures made about this time are still existing, and include very beautiful parts of the New Forest (Ridley Wood, Bratley, Bramble Hill, Malwood, Bignell, and others), the natural reproduction and regeneration of which appear to have been assisted by the sowing of seeds, as Roger Taverner mentions that some of the woods were "set" with Oak, and Beech or Thorns. Additional assistance was given in 1601 by *An Act to avoid and prevent Divers Misdemeanours in idle and lewd persons*, which among other things ordered "punishment for illicit cutting and mischievous spoiling of woods, trees, or poles."[1]

[1] This Act was the first ever applied to Ireland, in 1634 (Charles I.); but it appears to have been used only for protecting orchards and young trees in the "plantation" districts.

But the national outlook for timber generally, and for Oak for shipbuilding in particular, had already been forced upon the serious attention of Government during the time of Elizabeth, as is shown by the nature of enactments at this time.[1]

As we know from Taverner's survey of 1565, the "setting" or sowing of acorns and beech-mast was already then practised in woods, but what is now known as "planting"—in contradistinction to "sowing" of seed, "layering" or "plashing" of branches, or "setting" of slips or cuttings—seems to have been only introduced into woodlands (though previously practised in churchyards and ornamental grounds) early in the seventeenth century.[2]

"When the Spanish Armada was wrecked [in 1588], in one of the ships stranded on the coast of Devon was found a paper of instructions to the Admiral, telling him, above all, to cut down and destroy the Forest of Dean, so that the navy of England might be effectually crippled. This paper fell into Lord Burleigh's hands, and alarmed him and the whole nation. Among the projects submitted to him for providing timber for the navy in some inland locality which could not be so easily reached as Dean Forest by an enemy, was a scheme to enclose 13 acres in a corner of Cranbourne Chase, in Windsor Forest, and sow it with acorns, as an experiment. Lord Burleigh stretched his powers over the Forest so far as to get this done,"—and thus was said to have been inaugurated "the system of rearing Oak woodlands where they had never previously existed."[3]

Apparently therefore, down to about the end of the sixteenth century, all "plantations" formed were really made by sowing; and it seems probable that planting with live-plants was only introduced early in the seventeenth century owing to the acorns, &c., set being eaten by mice and voles.

[1] In 1581 *An Act touching Iron Mills near unto the city of London, and the River of Thames* prohibited the conversion of woods and underwoods into fuel for iron-smelting within 22 miles of London or of the river Thames; but it did not apply to parts of the Weald of Surrey, Sussex, or Kent, 18 miles (or more) from London, and 8 miles (or more) from the Thames. And in 1585 *An Act for the Preservation of Timber in the Wilds of the Counties of Sussex, Surrey, and Kent, and for the Amendment of Highways decayed by Carriages to and from Iron Mills there*, prohibited the conversion of good timber-trees into charcoal for iron-smelting, because "it is thought that the great Plenty of Timber which hath grown in those parts hath been greatly decayed and spoiled, and will in short Time be utterly consumed and wasted, if some convenient Remedy therein be not timely provided." So long as the great woods were still in existence on the Surrey, Sussex, and Kent Weald, iron was largely produced there. But the discovery of coal, the opening up of mines in the north, and the exhaustion of the necessary supplies of wood for charcoal caused the iron trade of the south to dwindle away. Smelting-furnaces were gradually closed, the last of them (at Ashburnham in Sussex) being extinguished in 1809.

[2] It would be difficult to fix the date when planting for timber was first begun in England, but planting for ornament certainly took place long before planting for profit was ever thought of. "A statute was passed A.D. 1307 and 35 Edward I., the title of which is *Ne rector arbores in cemetrio prosternat*. Now, if it is recollected that we seldom see any other very large or ancient tree in a churchyard but yews, this statute must have principally related to this species of tree; and consequently their being planted in churchyards is of much more ancient date than the year 1307." (White's *Natural History of Selborne, Observations on Vegetables: Yew.*)

[3] W. Menzies, Deputy-Surveyor of Windsor Forest, *Forest-Trees and Woodland Scenery*, 1875, p. 132.

The first recommendation known to me regarding planting with live plants in woodlands is contained in Arthur Standish's *New Directions of Experience for the Increasing of Timber and Firewood* (2nd edit., 1615, Preface, p. 8):—

Many say that they have set Akornes, Beech-maste, Chestnuts, and other seeds of wood, kernels, and stones of fruit that never came up, which can allege no other reason but that they were devoured by Field-mice, for so they show themselves being snouted like a swine, or a moule, which the House-mice be not. . . . The remedy for such as would raise plants is by nurseries, where the mice may be destroyed by traps.

Before this, however, ere the close of the sixteenth century, extensive enclosures and "plantations" (*i.e.*, sowings) of Oak were ordered in the royal New, Dean, and Windsor forests, because the national timber supplies were diminishing, while the demands for Oak for shipbuilding were rapidly increasing. Moreover, Queen Elizabeth had alienated portions of the forest-lands by letting them on lease or in fee-farm, and this led to a good deal of "wastage" or clearance, even though the leases stipulated that the woodland tracts were to be preserved as woods or coppices. James I. continued the same policy, which, in fact, was general down to 1701 (Queen Anne), when it was enacted—

That no "Grant, Lease, or other Assurance" should be made "of any Manors, Messuages, Lands, Tenements, Rents, Tithes, Woods, or other Hereditaments (Advowsons of Churches and Vicarages alone excepted)," unless it were made for a term "not exceeding one and thirty years, or three lives, or for some term of years determinable upon one, two, or three lives."

Though he made no new enactments, James I., who had already in Scotland continued the attention given to Arboriculture by his predecessors on the Scottish throne, seems to have taken great personal interest in the endeavours that were made to preserve the timber in the royal woodlands. Himself an ardent planter, more than once he drew the attention of his subjects to the way in which the provisions of the *Statute of Woods* were evaded in private woodlands, and exhorted them to attend to its provisions; and he set a good example in his own woods. In the instructions issued to a commission concerning "Woods" (*State Papers, Domestic*, 1607), it was ordered that the things to be considered by the commissioners and the jury were to include—

A Survey of the number of Coppice woods; how many acres each Coppice containeth; of how many years' growth the same is; what every Coppice is worth by the acre; in whose possession the same is; if granted to any person, then for what term and upon what consideration; whether the trees and the standils be preserved in every Coppice according to the Statute; and what waste and spoil hath been made in the same Coppices or any of them, and by whom. . . . To consider how many acres of Coppice woods will be necessarily reserved for the fencing and enclosing of new woods to be raised, that the number of the trees sold may be trebled by that planting, and whether the aldermores [*i.e.*, alder bogs], lops of thorns, and such like underwoods will be sufficient for continuing the enclosure.[1]

[1] A somewhat similar survey of the wood and timber and soil of the Forest of Dean was ordered in 1638 (Charles I.)

In addition to these instructions concerning "woods," King James also had a survey made in 1608 of the timber in the royal forests, parks, and chases, and ordered the ploughing of the land for the raising of new woods, the gathering of acorns, and the sowing, planting, or dibbling of them "by men's hands." In fact, he caused a rough-and-ready (but quite a definite) working plan or scheme of management to be prepared for all the royal woods throughout England.[1]

James I.'s strong personal interest in timber-growing is well shown by his action with regard to a small book or pamphlet of thirty-four pages, by Arthur Standish, entitled *New Directions of Experience . . . for the Increasing of Timber and Firewood.* This pamphlet urged sowing and planting (*i.e.*, with live-plants, see page opposite); and it met with so much approbation from James I. that a second edition was issued in 1615, which included among the prefatory matters a royal proclamation "By the King, To all Noblemen, Gentlemen, and other our loving Subjects, to whom it may appertaine." In this the "severall good projects for the increasing of Woods" were recommended to "be willingly received and put in practice," in order to restore the decay of timber "universally complained of" within the realm. The aim and objects of this pamphlet are thus set forth in the title-page of this second edition (1615):—

NEW DIRECTIONS OF EXPERIENCE AUTHORIZED BY THE King's most excellent Majesty, as may appeare, for the increasing of Timber and Fire-wood, with the least waste and losse of ground. WITH A NEARE ESTIMATION, what millions of Acres the Kingdome doth containe; what Acres is waste ground, whereon little profit for this purpose will arise. Which waste being deducted, the remaine is twenty-five millions; forth of which millions, if two hundred and forty thousand Acres be planted and preserved according to the directions following, which is but the hundred part of the twenty-five millions, there may be as much Timber raised as will maintaine the Kingdome for all uses for ever. And how as great store of Fire-wood may be raised, forth of hedges, as may plentifully mainetaind the Kingdome for all purposes, without losse of ground; so as within thirty years all Spring-woods may be converted to Tillage and Pasture. By Arthur Standish. Anno Domini MDCXV.[2]

Under Charles I. certain abuses of the forest laws were again revived. He alienated large portions of the Crown forest-lands by grant and sale, while he endeavoured to claim and to possess himself of tracts previously leased by Elizabeth and James I. Straining the laws, he made the chief justice in eyre hold a justice seat annually in place of only once in three years, and juries were suborned to find by inquisition the king's title to such lands. Charles' attempts to revive the abuses of afforestation, as regards purlieu and new lands, became at length so unbearable that it was finally curbed by *An*

[1] This is to be found among the Cottonian MSS., Titus, Book IV.; *tempore* James I., docketed as *Treasury Office; Increase of Revenue.* Under the head of *Planting, Increasing, and Preserving of Woods*, the then existing 30,000 acres of coppices were to be raised to 81,000 by adding 51,000 acres in fifteen years. These 3400 acres of new woods annually were estimated to cost £2102, 18s., or £31,543, 10s. for the whole 51,000 acres; and the net income derivable after fifteen years was estimated to be £21,600 per annum.

[2] It seems remarkably strange that Evelyn does not appear to make any mention whatever of Standish's work in his *Sylva.*

Act for the Certainty of Forests, and of the Meets, Meers, Limits, and Bounds of the Forests, in 1640, better known as the *Act of Limitation of Forests*. This determined once and for ever that the boundaries of the royal forests were to be what they had been in 1622 (twentieth year of James I.)—"any Perambulation or Perambulations, Presentments, Extents, Surveys, Judgments, Records, Decrees, or other Matter or Thing whatsoever to the contrary notwithstanding"—for the whole country was now tired of the vexatious tyranny of the forest laws, and resolved to end the nuisance. No place was to be accounted as still being forest where no justice seat, swainmote, court of attachment, &c., had been held within sixty years. Commissions were to be issued for ascertaining the true boundaries of all forests, as in 1622, and lands disafforested were to be excluded from the forests subject to forest laws; while the tenants, owners, &c., of such excluded lands (purlieus) were to enjoy their ancient rights of "Common and other Profits and Easements within the Forest." This ended the tyranny of the forest laws, because it very soon led to the virtual abolition of the forest courts.

At the same time, however, this Act gave fresh impetus to the transformation of woodlands into arable and pasture lands, and large sales of timber turned many well-wooded tracts into barren stretches of moor and heathy waste. Consequently, although much was done during the Commonwealth to promote the growth of timber within the Crown forests, the "wastage" of private woodlands went on rapidly.

Soon after the Restoration, *An Act for the Punishment of unlawful cutting or stealing, or spoiling of Wood and Underwood, and Destroyers of young Timber-trees* was passed in 1663. It applied to woodlands generally, and amplified and extended Elizabeth's Act of 1601 to misdemeanants, procurers, and receivers. It ordered punishment of suitable damages to the owner and a fine up to 10s., or in default thereof a whipping and up to a month's detention in the house of correction for the first conviction, one month's hard labour in the house of correction for a second offence, and on a third conviction they "shall be taken, adjudged, and deemed as incorrigible Rogues." And in those days a rogue of the second degree could be put to death as a felon, if he were above eighteen years of age.[1]

When Charles II. ascended the throne in 1660, the scarcity of Oak-timber for the navy had become so alarming that the Commissioners of the Navy asked the newly founded Royal Society to suggest a remedy. The first result of this application was that the Society's reporter, John Evelyn, on 15th October 1662, read a paper before it, which was afterwards expanded and published in 1664 under the title of *Sylva; or, A Discourse of Forest Trees, and the Propagation of Timber in His Majestie's*

[1] Before that, in 1661, *An Act to prevent the Unlawful Coursing, Hunting, or Killing of Deer* "in any Forest, Chase, Purlieu, Paddock, Wood, Park, or other Ground where Deer are or have been usually kept within the Realm of England or Dominion of Wales" had been passed, and a more generally comprehensive *Act for the better Preservation of Game and for securing Warrens not inclosed*, which authorised the appointment of gamekeepers, was passed in 1670; but neither of these, nor any of the subsequent enactments regarding game in general, had special reference to forests or woodlands.

Dominions.[1] This classic work of the British Forestry of that date was written, as the Preface tells us—

> Only for the encouragement of an *Industry*, and worthy *Labour*, too much in our days neglected, as haply esteem'd a consideration of too sordid and vulgar a nature for *Noble Persons* and *Gentlemen* to busie themselves withal, and who oftener find ways to *fell* down and destroy their *Trees* and *Plantations*, than either to *repair* or *improve* them.

The straits of Britain for timber at that time may be understood from the fact that in the same year (1662) an Act was passed prohibiting the importation of pitch, resin, deal boards, fir, and timber from the Netherlands or Germany "under any pretence whatever," in order to encourage the growth of trees in England and to develop the growing timber trade with the North American Colonies—a prohibition which was repealed as regards Germany in 1803, while an import duty was placed on timber, tar, &c., in 1807.

It will thus be seen that for over 350 years at least there was a constant fear of the demand far exceeding the probable supply; and that even so early as about 250 years ago Britain was already dependent on her American Colonies for timber, though she still strove to maintain home-grown supplies of Oak, because English Oak was considered the best timber in the world for shipbuilding.

In 1667 another survey of the Forest of Dean was ordered, with the result that in 1668 *An Act for the Increase and Preservation of Timber within the Forest of Dean* was passed. Its main provisions were that, out of the total estimated area of 23,000 acres, 11,000 acres (10,000 being part of the waste lands) might be enclosed within two years, "and shall be made and reputed a Nursery for Wood and Timber only"; and that when the wood and trees on these 11,000 acres, or any part of them, had outgrown danger from deer and cattle, such portions (of 500 acres or more) might be laid open and in common, while a like area of waste might be enclosed. Under this Act 8487 acres were soon enclosed and planted, while the remaining 2513 acres were also enclosed some time afterwards; and it was chiefly from these sources that supplies of navy dockyard timber were obtained from about 1740 onwards.

Thirty years later a similar Act had, in 1698 (William III.), to be passed for the New Forest, authorising the immediate enclosure of 2000 acres, and of other 200 acres annually for twenty years, thus making 6000 acres in all. And here again, as the young woods should outgrow danger from the browsing of deer and cattle, the enclosures were to be removed and fresh

[1] It met with a favourable reception, and went through four editions in about forty years; and before Evelyn's death, in 1706, it had induced many landowners to make Oak and other timber plantations for profit. The sixth to the eleventh editions, edited by A. Hunter, M.D., appeared between 1786 and 1825, when interest had again become awakened by the serious outlook with regard to supplies of timber for Britain's growing demands, before the introduction of steam communication by land and water had simplified this problem. The last or twelfth edition was an abridgment called *Dendrologia*, issued in 1827 by J. Mitchell, and nothing short of an insult to Evelyn's classic work. The best edition is the fourth, dated 1705, the form in which it was last revised by the author.

land enclosed, "to remain in possession of the Crown for ever, as a Nursery for Wood only"; so that ultimately the total area under wood was evidently intended to amount to twice 6000 acres, or 12,000 acres in all. The pollarding of trees, and "lopping and topping" to provide browse-wood for the deer, were prohibited. Charcoal was not to be made within 1000 paces of any enclosure, while right of common, of pasture, &c., was preserved in the forest. So far as the actual forest laws were concerned, neither of these two Crown arboricultural Acts of 1668 and 1698 altered them.[1]

Shortly after this, in 1705, a careful survey was made of the Forest of Dean, and a rough, simple working-plan for its management prepared, by Edward Wilcox, Surveyor-General of Woods, which was sanctioned by Lord Godolphin, the Lord High Treasurer. In his memorial to the Treasury the Surveyor-General stated—

That he had carefully surveyed the Woods in the Forest of Dean, and found them very full of young Trees, Two-third Parts whereof were Beech, which overtopped the Oaks, and would prevent them from ever growing up to be Ship Timber, so as to answer the Purposes intended by the Act of Parliament; and setting forth, that 11,000 Acres had formerly been enclosed; and that if the same should be divided into Sixteen Parts, and One-Sixteenth Part, being near 700 Acres, should be cut down each Year, and enclosed, leaving Standards of Oak or Beech, each Cutting would yield £3500, and Room would be given for the Standards to grow and come to Perfection.

The inhabitants of the forest objected to this as interfering with their rights of herbage and pannage; but the Crown right to enclose 11,000 acres was maintained as incontestable. The forest seems then to have been at its best; but soon after 1712 proper care was not given to it, the forest courts

[1] In 1698 *An Act for planting and preserving Timber Trees and Woods* was passed for Ireland. The preamble stated that: "Forasmuch as by the late rebellion in the Kingdom, and the several iron-works formerly here, the timber is utterly destroyed, so as that at present there is not sufficient for the repairing the houses destroyed, much less a prospect of building and improving in after-times, unless some means be used for the planting and increase of timber-trees."

The remedial measures prescribed were that—(1) All resident freeholders having estates to the value of £10 yearly and upwards, and all tenants for years at a rent exceeding that sum having an unexpired term of ten years, were required, under a penalty, from and after March 25, 1703, to plant every year, for thirty-one years, ten plants of five years' growth of Oak, Fir, Elm, Ash, or other timber; and owners of iron-works were required to plant five hundred such trees annually, so long as the iron-works were going. (2) Every occupier of above 500 Irish acres was required to plant and enclose, within seven years of the passing of the Act, one acre thereof, and preserve the same as a plantation for at least twenty years. (3) All persons and corporations seized of lands of inheritance were charged with the planting of their proportion of 260,600 trees yearly of Oak, Elm, or Fir for a period of thirty-one years. The proportions in which these trees were to be planted in each county were given in a list in the 4th section of the Act, and the proportion in which each county was to be planted was to be apportioned by the grand juries of baronies and parishes at each summer assizes.

A further provision gave tenants planting under the statute a right to one-third (increased by a later Act to one-half) of the timber planted. This was followed by several later Acts for the same object. That of 1702 abolished the duties on unwrought iron, bark, hoops, staves, and timber, and forbade exportation of these commodities except to England.

no longer being kept regularly, and the forest officials being guilty of abuses and neglect.

Despite everything Government could do in the Crown forests, however, matters concerning timber seemed to be gradually drifting from bad to worse. Evelyn indicates this in the opening words of the fourth edition (1706) of *Sylva* in

"Regretting the impolitic diminution of our timber, . . . caused through the prodigious havoc made" by those who "were tempted, not only to fell and cut down, but utterly to extirpate, demolish, and raze, as it were, all the many goodly woods and forests which our more prudent ancestors left standing, for the Ornament and Service of their Country."

The national concern at the time is evident both from the legislation then enacted and from the attention paid to planting by large landowners. In 1704 (Queen Anne) *An Act for encouraging the Importation of Naval Stores from Her Majesty's Plantations* (i.e., *Colonies*) *in America* prohibited any one "to cut, fell, or destroy any Pitch-Pine Trees or Tar Trees" under 12 in. diameter at 3 ft. above ground (unless within fenced enclosures) in the North American Colonies, under penalty of £5 for each offence; while the setting fire to Pine-woods or Tar-trees was punishable with a fine of £10 for each offence. In 1710 and 1713 additional protection had to be given to the Colonial woodlands, upon which Britain had become mainly dependent for supplies of tar, &c., during the time of her great naval wars. Under the Act of 1713 bounties of £4 per ton were given for tar and pitch, £3 per ton for rosin, and 20s. per ton for masts imported into England from the mountainous tracts of Scotland, where "great Store of Pine and Fir trees, fit for masts, and for the making of Pitch, Tar, Rosin, and other Naval Stores," then existed.

In Queen Anne's reign two Acts were passed relative to game, but the next statute referring to woods generally was *An Act to encourage the Planting of Timber-Trees, Fruit-Trees, and other Trees, for Ornament, Shelter, or Profit; and for the better Preservation of the same; and for the Preventing the Burning of Woods*, passed in 1714 (George I.) This made parishes liable to owners for malicious damage to timber-trees, and directed how offenders should be dealt with and punished. But it very soon had to be amended and extended, in 1719. Offences against game and timber seem to have been very frequent about this time, and apparently the royal forest officers were often notorious poachers and deer-stealers. In 1718, forest officers illegally killing deer or confederating with deer-stealers were to be fined £50, or in default to be imprisoned for three years and set in the pillory; while, in 1722, further legal protection was given to plantations by *An Act for the more effectual punishing wicked and evil-disposed Persons going armed in disguise, &c.*, which ordered that persons convicted of being armed "and having his or their faces blacked, or being otherwise disguised," in any forest, park, or enclosed ground, or of having maliciously destroyed trees, "shall be adjudged guilty of Felony, and shall suffer Death as in Cases of Felony, without Benefit of Clergy." And in 1737 (George II.) the "hunting, taking in toils, killing, wounding, or taking away any Red or Fallow Deer in any open or unenclosed Forest or Chase" was made punishable with seven years' transportation to America for a second conviction, while a similar penalty was incurred for beating or wounding forest-keepers and pages.

Besides various amendments made to the game laws in George II.'s reign, the Acts more immediately concerning woodlands consisted in making the illegal burning "of any Gorse, Furze, or Fern, growing or being in or upon any Forest or Chase, within that part of Great Britain called England" punishable with a fine of 40s. to £5; and in 1756 an Act was passed *For enclosing by the mutual Consent of the Lords and Tenants, Part of any Common, for the Purpose of planting and preserving Trees fit for Timber or Underwood; and for more effectually preventing the unlawful Destruction of Trees.* This Act was amended and rendered more effective in 1758.

In Scotland arboriculture was already practised to some extent about the middle of the seventeenth century. The Botanic Garden was founded at Edinburgh by Dr Balfour in 1670, and apparently the bounties offered under the Act of 1713 induced some of the great landowners to plant on a large scale (see Part II., chap. ii., *Larch*). In England a great stimulus was also given to arboriculture, though this often only took the form of ornamental planting for the beautification of estates, and one of the most notable examples of this was the Duke of Northumberland's arboretum at Syon House (near Brentford, Middlesex). By about 1730 extensive planting was general throughout the United Kingdom, and some of the oldest of the existing woods date from that period, while the formation of large nurseries for supplying young trees for planting appears to have become an established business between 1730 and 1760. Kew Gardens were also formed in 1760, which have long been by far the most celebrated arboretum in the kingdom.

George III.'s long reign was extremely prolific in forest legislation. In 1765 an Act was passed offering bounties for the import from the North American Colonies of "any good, sound, and merchantable Deals, Planks, Boards, and Timber" into any part of Great Britain. Leaving out of consideration such enactments as were more particularly of the nature of general game laws, there were many directly affecting the growth of timber in the royal forests and private woodlands. Two very important Acts were passed in 1766—namely, *An Act for encouraging the Cultivation, and for the better Preservation of Trees, Roots, Plants, and Shrubs*, relating more especially to timber-trees (*i.e.*, Oak, Beech, Ash, Elm, Fir, Chestnut, and Aspen), and an amending *Act for the better Preservation of Timber Trees, and of Woods and Underwoods; and for the further Preservation of Roots, Shrubs, and Plants*, which added Walnut, Cedar, Lime, Sycamore, and Birch to the above list of timber-trees; and this protection was afterwards also extended, in 1773, to Poplar, Alder, Maple, Larch, and Hornbeam. In 1769 and 1770 legal protection was given to *Hollies, Thorns, and Quicksets in Forests, Chases, and Private Grounds;* while the Statute-book simply abounds with private Acts passed (more especially between 1796 and 1800) *for dividing, allotting, and enclosing* open fields, commons, and waste lands in most of the English counties.

But still the national outlook for timber grew gloomier and gloomier. The pressing want of Oak for the navy dockyards is clearly shown from the fact that the appointment, in 1771, of a Committee of the House of Commons to consider the supply of the navy timber immediately resulted in the passing, in 1772, of an *Act for the more effectually securing a Quantity of Oak Timber for the use of the Royal Navy.* This Act was neither more nor less than a prohibition of the extension of the trade of the East India Company, which was forbidden, under a penalty of £5000 for each ship "built, or begun to be built," to have shipping to the extent of more than 45,000 tons—the tonnage of the navy being then about 400,000 tons, and that of the whole British mercantile fleet being about 800,000 tons.

By a special Act of Parliament in 1786, a Royal Commission was appointed *to inquire into the State and Condition of the Woods, Forests, and Land Revenues belonging to the Crown;* and this Commission, consisting of three members, worked continuously till 1793, submitting in all seventeen reports, which are of great historical interest and much practical value to students of Forestry.[1]

The extreme seriousness of the national position at this time may be understood from short extracts from the Eleventh Report of the Royal Commissioners (dated 6th February 1792, pp. 14 and 15, and Appendices 14 to 24) regarding the national supplies of Oak timber and the requirements for shipbuilding.

Extract from Report.	Tonnage of British Fleets (Appendices 14 to 24).			
	In year	Naval.	In year	Mercantile.
"We shall only observe . . . that from the year 1730 to 1787, the Whole of the Forests, Parks, and Chases belonging to the Crown furnished to the Dockyards only 77,256 Loads of Oak Timber, being on an average of 57 years no more than 1356 Loads annually; that instead of yielding any clear Revenue to the Public, the Value of all they have produced has been expended on them, and a great sum besides, . . . and yet they now contain much less timber than in former times."—(1792, p. 15.)	1547	12,455	...	...
	1603	17,110	...	...
	1660	57,463	...	...
	1685	103,558	...	...
	1727	170,862	...	...
	1760	321,104	1760	486,740
	...	...	1770	682,811
	...	...	1780	618,853
	...	...	1785	859,606
	1788	413,667	...	...

Note.—The imports of foreign timber were then, as they now are, for by far the most part Pine- and Fir-wood; but the imports of this class increased *about tenfold* between 1720 and 1790.

[1] Appendix No. 1 to the Third Report (dated 3rd June 1788) gives a list of the Crown forests and woodlands—viz., New Forest, Alice Holt, Woolmer Forest, and South or Bere Forest (Hampshire); Windsor Forest and Cranbourne Chase, Windsor Great Park, Windsor Little Park (Berkshire); Richmond Park (Surrey); St James's Park, Hyde Park, Bushy Park, Hampton Court Park (Middlesex); Dean Forest (Gloucester); Greenwich Park (Kent); Waltham als Epping Forest (Essex); Whittlewood Forest, Salcey Forest, Rockingham Forest (Northampton); Whichwood Forest (Oxford); and Sherwood Forest (Nottingham). There were also some other lands, but they contained no stock of timber.

In criticising the condition of the two largest royal woodlands, the Dean and New Forests, they also remarked (p. 14) that—

> In consequence of the Act for Dean Forest, passed in 1668, 11,000 Acres were speedily enclosed and planted, and the trees in them regularly thinned and protected till they were past Danger from Cattle; and in New Forest, immediately after the passing of the Act in 1698, 1000 Acres were also enclosed and planted. But so sudden was the change in the Management of the Forests after the Commencement of the present Century, that *the Enclosures which had been made in New Forest were neglected, and the Trees were suffered to grow up so close, for want of proper Thinning, that few of them are likely ever to be fit for the Use of the Navy.* . . . Both these Acts contained Powers for making further Enclosures, on throwing open those first planted, when the Trees should be past Danger from Deer and Cattle, and under those Powers the whole of Dean Forest, containing 23,000 Acres, might before this Time have been successfully enclosed and completely covered with Great Timber, and not less than 24,000 Acres planted in New Forest, in addition to the former Woods: yet these valuable Powers have been so far neglected that there are now, in Dean Forest, only Four small Enclosures, containing about 660 Acres; and the whole of the Plantations in New Forest, since these first made, contain only 2274 Acres, *of which about* 800 *Acres are entirely destroyed by Rabbits, bred by the Keepers for their own Profit.*

The first of the above passages in italics shows the fundamental difference between the old English national system of **Arboriculture** and the object of modern **Sylviculture.**[1] Tough, curved rib-pieces and crooked knees, then wanted for shipbuilding, could only be produced by giving the Oaks plenty of room to spread out their crowns and grow into strong-limbed trees; whilst what is now desired are long, smooth, clean boles, that can only be produced by growing the trees in close canopy.

The second italicised clause is of particular interest, as it is the earliest recorded case known to me in which wholesale destruction was caused in plantations by rabbits, now one of the most destructive pests in our woodlands.

The use of iron and steam has completely revolutionised shipbuilding and navigation; but the direct effects of the old national system of growing Oak and other timber-trees as standards in copsewoods and in hedgerows are still to be seen very plainly in our woodlands. And the minds of landowners and land-agents are still more or less inclined to the old idea that trees require a much larger individual growing-space than is really essential if they are to be grown with profit.

The main outcome of the labours and recommendations of this Commission[2]

[1] The difference between **Sylviculture**, or modern Forestry, and **Arboriculture** is much the same as that which exists been **Agriculture** and **Horticulture**, or between a *wholesale* business and a *retail* trade.

[2] Their Third Report (1788) dealt specifically with the Forest of Dean, which was "by far the most valuable and the most proper for a Nursery of Naval Timber"; and the Sixth Report (1790) dealt with the New Forest. In 1800 an Act was passed appointing another Royal Commission (independent of that of 1786) to fix the boundaries of the New Forest and prepare a map of it. A perambulation was made in 1801, and the boundaries then fixed have ever since been accepted as the true boundaries. As funds for the survey were apparently difficult to obtain then, extensions of the Commission had to be obtained by Acts in 1801 and 1811; but the map was never made. In 1812 yet another Act

was the passing, in 1808, of *An Act for the Increase and Preservation of Timber in Dean and New Forests*, and in 1817 of the *Act to abolish the Offices of the Warden, Chief Justices, and Justices in Eyre*, when these duties were vested in the First Commissioner of Woods and Forests.

The Act of 1808 was a short Act, passed, as the preamble states, to try and overcome "the great and increasing difficulty" of procuring navy timber by giving better effect to the Acts of 1668 (Dean Forest) and 1698 (New Forest), "which said Acts have not been duly put in Execution." Power was again given to enclose up to 11,000 acres in Dean Forest and 6000 acres in New Forest, to be "inclosed and held in severalty . . . at one and the same time," the enclosures being made under Royal Commissions, while heavy penalties were attached for damage to fences or enclosures.

Besides urging extensive planting of Oak in the royal forests, the Commission also advised the formation of extensive plantations of Pine and Larch on the poorer tracts unsuitable for Oak, because the first experiments made with Pine in the south of England (in 1766, see Part II., *Scots Pine*) were giving great promise of profitable growth.

Numerous commissions were consequently issued for extensive planting of Oak and Conifers; and at the same time an impetus, which lasted down to about 1830, was given to private planting. Towards the end of the eighteenth and early in the nineteenth century large Conifer plantations were formed in Scotland, the chief planters being the Duke of Athole, the Marquis of Breadalbane, and Sir J. Grant of Strathspey. But extravagant ideas were formed of the possibilities of profit thus held out to landowners.

As regards the Scottish Larch plantations made by some of the great landowners towards the end of the eighteenth and early in the nineteenth century, it was asserted [1] that—

> Nothing in South Britain equals the extent and magnificence of those artificial forests which these lords of whole provinces have spread over their wild domains. . . . A tree, which, in fifty years, will produce a beam equal to an Oak of more than twice that duration, while, in contradiction to every other example, the durability and hardness of the wood are in no degree affected by the rapidity of its growth,—a tree which, if the Oak should fail, would build navies, and if the forests of Livonia or Norway or Canada were exhausted, would build cities, is an acquisition to this island almost without a parallel. In the present state of our relations with foreign countries, and even with our own Colonies, it is impossible to contemplate, without exultation, acquirements which contribute in so important a degree to render us independent of importation.

The country was, in truth, in great straits for naval timber. In 1810 Lord Melville addressed Mr Percival, the Prime Minister, on the decay and destruction of the national forests, pointing to the advance in the

(this time in special connection with the Act of 1808) was made ordering a map to be prepared within five years, and in 1817 a surveyor was appointed, who made a plan of the Forest. Only one copy of this exists, which is kept in the office of the Deputy-Surveyor at Lyndhurst. It was never signed and certified, as originally ordered. Minor Acts also dealt with the disafforestation of the forests of South or Bere (Hants, 1810) and of Parkhurst (Isle of Wight, 1812), and with the enclosure of commonable land within them, as well as with the better cultivation of navy timber in Alice Holt Forest (Hants, 1812).

[1] *Quarterly Review*, March 1813, vol. ix. p. 51; but see also Part II., *Larch*.

price of Pine and Fir timber, the increase in the demand for Oak, and the inability of the woodlands to meet this demand, and exhorted Government to take adequate steps to provide for the future instead of merely trusting to private commercial enterprise. He estimated then "that certainly not less than twenty millions (of acres) are still waste," and urged that they should be planted for the national welfare. About this time, too, the Society of Arts (London) tried to encourage planting by conferring medals as premia to landowners.

Monteath's *Forester's Guide and Profitable Planter* (1824), and Sir Henry Stuart's *The Planter's Guide* (1828), furnished texts for Sir Walter Scott's two Forestry articles, *On Planting Waste Lands* and *On Ornamental Plantations and Landscape Gardening*, in the *Quarterly Review* for October 1827 and March 1828. They dealt with planting for profit, shelter, and ornament; and apart from their literary value, they are still well worth reading. A careful distinction, often lost sight of since then, was drawn in these two articles between plantations for profit and those for ornament—or, in other words, between **Sylviculture** (or **Forestry**) and **Arboriculture**.

Despite the fact that planting was found to improve land,[1] however, there seems to have been a cessation of activity in planting after 1830. Maturing plantations showed that the very sanguine anticipations formed were seldom likely to be realised, and the prospects of profit were usually too uncertain to induce great landowners to embark on permanent investments of this particular kind, and more especially at the time when railways, offering more tempting investments, began to be built extensively. Although numerous minor Acts had been passed meanwhile, the next statute affecting Forestry and Arboriculture generally was the exemption of the New and Dean Forests from the *Act to facilitate the Enclosure and Improvement of Commons* in 1845 (Queen Victoria). But from this time onwards the economic position of the country as regards Oak and most other timber was entirely different from what it previously had been. About a hundred years ago the discovery was made that the oily Teak-tree of India possessed valuable properties for shipbuilding, and henceforth the country was saved from its chief anxiety in this respect. And when Britain emerged from her great Continental war with complete command of the sea, she could supply all her other wants with regard to coniferous timber from her North American Colonies and from other countries. After that, the replantation of the royal woods and forests no longer seemed of vital importance; and some of them were subsequently turned into national parks for recreation. The effect of the Continental wars was that large areas of woodland were converted into arable land, the stiff soils on which the Oak thrived best being also those most suitable for corn. And fresh land was seldom planted to replace the woodlands cleared away. Still, the planting of

[1] "Many of these trees, and more especially the Larch, are known to destroy the heath and to afford a shelter highly favourable to the growth of nutritious grasses. Thus even without including the timber in the estimate, the land on many great estates has already been, to all intents and purposes, doubled in value."—*Quarterly Review*, 1828, vol. xxxviii. p. 441.

Oak on the better woodland soils, and of Larch, Pine, and Fir on inferior land and exposed situations, went on fairly extensively until about the middle of last century, when the whole position was revolutionised by steam communication by land and water, and by the use of iron in shipbuilding, which now enabled foreign timber to be imported at a low price. Other economic changes have also gradually taken place since then, greatly affecting the once very profitable woodland portions of estates; and as timber, bark, and coppice-wood gradually sank in value as the result of free import trade, the existing woodlands have gradually come to be mainly game preserves and ornaments to large estates.

THIRD PERIOD.—From about 1850 onwards.

The manner in which the great economic changes caused by railway and steamship communications affected the royal forests can be easily understood by a very brief summary of events. In 1848 a House of Commons Committee considered the questions affecting the Crown forests, but never delivered any complete report, though an interim report was issued in 1849, and the draft of a report was also discussed. A Royal Commission was appointed in 1850 (Lord Portman presiding) to inquire into the rights and claims over the New Forest and Waltham Forest (Essex), which resulted in what is generally known as *The Deer Removal Act* of 1851. It did not affect the Forest of Dean, but empowered the enclosure of up to 10,000 acres in the New Forest, instead of the right to keep deer (and in addition to the 6000 acres enclosable under the Acts of 1698 and 1808), such enclosures to belong to the Crown, free of all common and other rights. When these enclosures had outgrown danger from cattle, they were to be opened to grazing, and new enclosures made; and a register was to be kept defining all rights of common and the owners of the same.

In 1852 the status of the Commissioners of Woods and Forests was determined more definitely than hitherto by *An Act to alter and amend certain Acts relating to the Woods, Forests, and Land Revenues of the Crown.* In 1861 the various statutes dealing with damage to woodlands, trees, and shrubs were consolidated and amended in the *Act . . . relating to Larceny and other similar Offences* (24 & 25 Vic. cap. 96, sect. 16, referring to "any Forest, Chase, or Purlieu"; and sects. 31 to 33 and 35, referring to "trees and woods"), while protection was at the same time given to ornamental trees and shrubs under the Act relating to *Malicious Injuries to Property* (cap. 97, sects. 20 to 22 and 53). Under these it was made felony to steal any tree, shrub, or underwood, or to destroy or maliciously injure the same with intent to steal, if the value be £1 in parks, avenues, or pleasure-grounds, or £5 elsewhere; and even if the value be only over 1s., on a third offence the larceny becomes a felony, and the malicious injury becomes punishable with two years' imprisonment with hard labour.

The Deer Removal Act of 1851 created so much bitter feeling locally, and such a public outcry for æsthetic reasons, that a Committee of the House of Commons was appointed to consider the whole question of the New Forest; and an amending Act was passed in 1877, by which the work of planting was stopped when only about 5000 acres had been planted, the enclosures were limited to 16,000 at any given time, and it was laid down that only plantations made since 1700 can be enclosed and replanted. This is the law now in force; and under it the older woods are being destroyed by gales and the decay of old age, without permission being given under the Act to replace the old trees by new growth. Thus while the unwooded parts are barren wastes and moors, the old woods are also gradually being destroyed by unrestricted commonage.[1] In the Forest of Dean, too, there had been so much friction with the mining population that, in 1874, a Select Committee of the House of Commons had also been appointed to inquire into and report on it.

In the meantime, while less attention was now being given to the growth of timber in the Crown forests, there were many private landowners, especially in Scotland, who planted largely about the middle of last century. After about 1845 drainage was better understood and practised, so that timber crops had a fairer chance of doing well. The Highland and Agricultural Society of Scotland did much to encourage Arboriculture, and a further stimulus to Forestry was given in 1854 by the formation of the (now Royal) Scottish Arboricultural Society for the advancement of Forestry in Scotland. For half a century these two Scottish societies have been the only two bodies that have continuously and consistently urged the claims of Forestry to receive more attention than hitherto, and with an assiduity that now at length seems to be achieving something like substantial progress.[2]

In 1855 another *Quarterly Review* article (vol. xcvi. p. 431), entitled *The Forester*, reviewed the well-known works by Brown, Johns, and Selby, then recently published, and the first and second reports of the Commissioners of Woods and Forests under the new Act of 1851. This article dealt with planting for profit on waste lands, and in situations where agricultural crops did not pay; and it gave very sound advice concerning soil and situation, drainage, enclosure, fencing, soil-preparation, pit-planting and notching, the number of plants per acre, and the best time for planting.[3] Though

[1] The woods in the New Forest are now—From 30-40 years, 5705 acres; 40-65 years, 4278 acres; 65-90 years, 4080 acres; 90-115 years, 2230 acres; over 115 years, 1377 acres,—total, 17,670 acres. Of the remaining 47,067 acres belonging to the Crown, 40,478 acres are open heath and pasture, the enclosure and planting of which are absolutely prohibited by the Act of 1877.

[2] In England this lead was not followed till 1881, when the *English Arboricultural Society* was formed; and it was not till 1901 that the *Irish Forestry Society* was established.

[3] On all of these important points much sound advice was given, while well-considered and shrewd remarks were made on the tending of plantations. It included instructions concerning the pruning of hardwoods with a view to correct the errors of injudicious thinning, consequent on the erroneous ideas then prevailing as the result of the old national system of Arboriculture having for its main object the growth of branching Oak timber for shipbuilding, while it also advised that "in Fir plantations . . . no pruning should be allowed, as the operation injures both the health of the individual and the

it contains much that is technically incorrect, yet its main outlines are thoroughly practical; and the article is just as well worth reading now as it was fifty years ago.

The retrograde passiveness which existed about this time is noticeable in a later *Quarterly Review* article, in 1876 (vol. cxlii. p. 50), on *Ornamental and Useful Tree-Planting.* In reviewing new editions of Brown and Selby's works and five other books, of which the chief was Grigor's *Arboriculture*, this article dealt with the more purely ornamental side of Arboriculture. It was an essay on landscape gardening, and its tenor was that—

> If, as was said in the outset, trees are a special passion with Englishmen, the future of our woodlands and forests demands that an interest in their culture and conservation should be spread far and wide among our countrymen, and rise superior to utilitarian calculations or the selfish pleadings of private interest.

And very much the same careless tone also prevailed as regards legislation. The immediate pressure about timber having been relieved, all the former concern as to the national importance of British woodlands appears to have become completely forgotten: it seems to have passed absolutely and entirely from the recollection of the public, and of their representatives in Parliament.

In Scotland, however, the necessity for instruction in Forestry was being kept in view by the Highland and Agricultural Society and the Scottish Arboricultural Society. A Forestry Exhibition was held at Edinburgh in 1884, in the hope that a surplus would be earned sufficient for the endowment of a Chair of Forestry in the Edinburgh University; but though in other respects successful, this object was not achieved.[1] It led, however, to the appointment of a Select Committee of the House of Commons in 1885 to consider "*whether, by the establishment of a Forest School, or otherwise, our woodlands could be rendered more remunerative.*"

After collecting much interesting evidence, the Committee reported on 4th August 1887 that—

> The woodlands belonging to the State are comparatively small, though even, as regards them, the difference between skilled and unskilled management would itself more than repay the cost of a forest school. The woodlands in private hands, however, are far

quality of the wood." At that time the ideas about thinning (and consequently about the number of trees per acre allowed to remain for the mature timber crop) were extravagant, the ordinary rule-of-thumb of the forester being that the trees should stand at a distance from each other equal to one-third of their height—that is to say, a wood of trees that had run up to a height of 90 ft. would only bear a crop of 48 or 49 trees per acre, and this quite irrespective of the fact that a shade-enduring crop of Beech, Sycamore, Spruce, or Silver Fir should stand far thicker than a light-demanding crop of Oak, Larch, or Scots Pine. And this rough rule appears to have been commonly applied in practice, because it was estimated "that it takes 2200 full-grown trees, or the matured crop of 44 acres of woodland, to furnish timber for a single 74-gun ship,"—which shows a stock of only 50 trees per acre, standing about 30 ft. apart.

[1] In 1893 an Exhibition of Horticulture and Forestry was held at Earl's Court (London); in 1901 the Irish Exhibition at Cork had a section for Forestry; and since 1902 the Forestry exhibits have formed a regular part of the Highland and Agricultural Society's Show in Scotland. In 1904 the Royal Agricultural Society of England also formed a Forestry Exhibition at their annual Show in London.

more considerable, and the total area of woodlands amounts, according to the agricultural accounts, to 2,788,000 acres. . . . Moreover, strong evidence has been given before your Committee that large tracts of land in the United Kingdom, especially in Scotland and Ireland, might be planted with advantage. The forests in India and the Colonies must also be taken into consideration, and on the whole, the forest area in the British Empire is greater than that belonging to any other country. Your Committee are satisfied that, so far as Great Britain and Ireland are concerned, the management of our woodlands might be materially improved. Moreover, the present depressed values render economical and skilful management even more important than if the range of prices were higher, though it is probable that, with the waste of forests elsewhere, a brighter future is in store for home Forestry, and that some considerable proportion of the timber now imported, to the value of £16,000,000, might, under more skilful management, be raised at home.

Nearly every other civilised State possesses one or more forest schools. In this country, on the contrary, no organised system of Forestry instruction is in existence excepting in connection with the Indian service.[1]

The witnesses examined before the Committee have been generally and strongly of opinion that the establishment of forest schools, or at any rate of some organised system of forest instruction, would be very desirable; but they have differed considerably as to the best mode in which this might be effected. There is a general agreement that the establishment of a Forest Board would be a wise step.

As regards the formation of a forest school, more than one centre of instruction would be desirable; though in the first instance it might be well to establish one school only. . . . This school would doubtless be situated in England, but a school for Scotland is also urgently needed, and your Committee are of opinion that it would probably be desirable to found another in Ireland.

. . . .

Apart from the question of actual profit derived from tree-planting, its importance as an accessory to agriculture is shown by the effects which woods have in affording shelter and improving the climate; and your Committee are of opinion that, whilst on public and national grounds timber cultivation on a more scientific system should be encouraged, landowners might make their woods more remunerative were greater attention paid to the selection of trees suitable to different soils and to more skilful management after the trees are planted.

Your Committee have had evidence that, apart from any immediate pecuniary benefits, there would be considerable social and economical advantages in an extensive system of planting in many parts of the kingdom, especially on the west side of Ireland and in the Highlands of Scotland. This subject is one of great importance, and well worthy of early consideration.

They also recommended the creation of a Board of Forestry, to give effect to the establishment of forest schools and conduct examinations in Forestry.

These recommendations were given effect to, to a slight extent, by power being conveyed, under the *Board of Agriculture Act* of 1889, to the Board to undertake the collection of statistics relating to Forestry and the inspection of schools (except Cooper's Hill College and public elementary schools) in

[1] In 1866 the necessity of having young officers trained in Forestry was felt with regard to the Indian forests. In 1866 the first competition for appointments to the Indian Forest Service was held, and for some years the probationers were trained in Germany (1867-75) and in France (1867-85). This Continental system of training ceased in 1886; and since 1885 the technical education has, for the most part, been given at the Indian Engineering College, Cooper's Hill, Surrey, by two professors of Forestry, assisted by teachers of the cognate sciences. The course of training, however, still includes a six months' residence in a North German forest and prolonged tours in the forests of France and Southern Germany, in order to give opportunities, not to be had in this country, of seeing Forestry on a large scale.

which technical instruction is given in Forestry; to aid any system of lectures or instruction connected with Forestry; to inspect and report on any examinations in Forestry; and to make or assist in inquiries, experiments, and research for the purpose of promoting Forestry.[1]

The Select Committee on Forestry had, in their report of 1887, thought it right to call attention to the "unskilled management" of the Crown woodlands generally, and "the present unsatisfactory condition of the New Forest" in particular, owing to the Act of 1877. Accordingly another Select Parliamentary Committee was appointed in 1889 *to inquire into the Administration of the Department of Woods and Forests and Land Revenues of the Crown.*[2]

In their report in 1890, the Committee found the administration by the Commissioners of Woods and Forests satisfactory, but recommended that all the Acts relating to timber production in the Crown woods should be repealed:—

> The allotments set out and allotted to the Crown in severalty in Alice Holt Forest, Bere Forest, and Parkhurst Forest were by the Acts devoted to the growth of Timber for the Royal Navy. As no timber is required by the Admiralty from these properties, the restriction as to their being devoted to the growth of timber, and also any similar enactments affecting the New Forest and the Forest of Dean, should be repealed.

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[1] But these powers were limited, and when interrogated on the subject in Parliament on 23rd March 1891, the President of the Board of Agriculture intimated that he had "no power of giving effect directly to the recommendations of the Select Committee, either as regards the establishment of a school or schools of Forestry or the creation of a Board of Forestry." Under such powers as were conferred, however, the Board of Agriculture began in 1891 to pay £100 a-year towards the Lectureship in Forestry instituted (in 1889) at Edinburgh University, and £250 a-year as one-half of the salary of the Professor of Agriculture and Forestry at the Durham College of Science (founded at Newcastle-on-Tyne in 1891), and, since 1892, £150 a-year towards the free instruction of foresters and gardeners at the Royal Botanic Garden, Edinburgh, and similar aid towards instruction at the Glasgow Technical Institute in the West of Scotland (see also p. 42).

[2] The Crown woods and forests were found to then consist of,—Windsor Park and woods (15,175 acres); the New Forest (64,834 acres); the Dean Forest (18,710 acres); other woods and forests in Cheshire, Gloucestershire, Hampshire, the Isle of Wight, Northamptonshire, Surrey, and other counties (16,574 acres).

The status of these national woods was shown to be as follows:—

Windsor Forest (15,175 acres).—Of this, 5355 acres are domain attached to Windsor Castle, and 9820 acres are not regarded as part of the residential property of the Sovereign. The ranger, appointed under section 135 of 10 Geo. IV., has sole control of the deer, game, fish, and herbage.

The New Forest.—The income from this large tract of land is small, but the profitable rights of the Crown are very limited. The open forest is subject to rights of common, timber in recent inclosures is immature, and in the older woods the rights of the Crown are greatly restricted by the Act of 1877. The policy then adopted was, that the New Forest should be administered principally with regard to the preservation of its ornamental character, and not with a view to profit.

The Forest of Dean.—Owing to the rights of commoners and miners, only a comparatively small income is obtained from the surface; whilst, as in the New Forest, regard is paid to the preservation of the natural beauty of the woods. By customs confirmed by Act of Parliament, the coal, ironstone, and quarry stone are "galed" (leased) to free-miners only on perpetuity leases, which are in almost all cases alienated by the original "galees."

Fortunately this recommendation was not accepted. Though the New Forest is still being spoiled under the Act of 1877 (which ties the hands of the Commissioners of Woods and Forests and the Deputy-Surveyor), yet much has been done (see below) within the last ten years to make the Forest of Dean a good timber-producing estate and a place of instruction in Forestry.

There had apparently even been some talk of selling the Crown rights in the Forest of Dean, because the Committee remarked regarding it that—

> Possibly a larger income might be obtained by the sale of the surface and the re-investment of the proceeds; but a difficult question would have to be dealt with in the purchase of the right of commonage enjoyed by tenants and freeholders of certain parishes. This would be detrimental to the welfare and repugnant to the feelings of the inhabitants of the district; whilst the destruction of the forest would be most regrettable.

Instead of any sale being effected, or the Acts regarding Arboriculture being repealed, a businesslike working plan was drawn up for the Forest of Dean in 1897, which now forms the Scheme of Management adopted.[1] This gave a general description of the forest, with details regarding the various enclosures (in blocks and sub-blocks), and made definite proposals for the future management, the main features of which will be more appropriately referred to in dealing with the *Management of Woodlands* (vol. ii., Part II.) This is the first instance of a thorough and comprehensive working-plan, drawn up more or less on the lines of the modern Continental system, being applied to the management of one of the great Crown forests.

A similar scheme was at the same time drawn up for the Highmeadow Woods estate[2]—adjacent to the Forest of Dean, and also under the charge of the Deputy-Surveyor—extending to about 3285 acres of enclosed woods, situated on both sides of the river Wye between Ross and Monmouth.

The twofold objects with which these two working plans were drawn up were thus described by Mr E. Stafford Howard, C.B., senior Commissioner of Woods and Forests:[3]—

> For some time past I have been anxious to introduce into the Forest of Dean and the Highmeadow Woods a more scientific and systematic system of forest cultivation than has hitherto been adopted. . . . It is desired not only to improve the prospective yield of the Forest, but also to establish such a system of management as may serve those who desire to study Forestry in this country with a good practical object-lesson, such as at the present time they have to go to France or Germany to find.[4]

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[1] *Report on the Forest of Dean, with Suggestions for its Management*, by H. C. Hill, H.M. Stationery Office, 1897.

[2] *Working Plan Report for the Highmeadow Woods*, by H. C. Hill, H.M. Stationery Office, 1897.

[3] *Annual Report of Commissioners of Woods and Forests*, 28th June 1897, p. 4.

[4] Long before this the Forest of Dean had already served some such purpose, because "foresters entrusted with the management of private estates come hither from all parts of the United Kingdom to take practical lessons in their art" (*Quarterly Review*, vol. xcvi., 1855, p. 457).

As the recommendations of the Parliamentary Committee of 1885-87 were neither acted on nor any longer met the case, the Royal Scottish Arboricultural Society in 1901 memorialised the President of the Board of Agriculture with regard to the improvement of British Forestry, and in February 1902 a Departmental Committee was appointed

To inquire into and report as to the present position and future prospects of Forestry, and the planting and management of Woodlands in Great Britain, and to consider whether any measures might with advantage be taken, either by the provision of further educational facilities, or otherwise, for their promotion and encouragement.

The Committee was composed mostly of officials and ex-officials, and the report was consequently characterised by narrowness and official reticence. It plainly showed the defects to be expected from the want of any proper representation of the landed interest and of business men, who could consider the subject without preconceived notions. The Committee's recommendations were therefore, in some important respects, rather unsatisfactory. No decided opinion was expressed as to either the desirability or the undesirability of extensive planting by the State, and no recommendation was made that Government might somehow or other try to induce landowners to plant timber for the improvement of rural conditions and the benefit of future generations. This Committee practically did little else than

endorse the conclusions of the Select Committee of 1885-87 as regards the neglected condition of Forestry in Great Britain, the possibility of improvement, and the necessity for the provision of better means of education.

They recorded their opinion—

13. That the yield of our woodlands can be materially improved admits of no doubt, and the evidence before us unanimously favours immediate and effective provision for bringing systematised instruction within the reach of owners, agents, foresters, and woodmen. This has been on all sides emphasised as the first requisite in any project for the improvement of forestry, and consequently stands out as the cardinal point of our recommendations.

These recommendations were summarised as follows :—

(*a*) That two areas for practical demonstration be acquired, the one in England and the other in Scotland, of not less than 2000 acres, if possible, nor over 10,000 acres in each case.[1] We suggest that the Alice Holt Woods in Hampshire be made available as soon as possible to serve as a Demonstration Area in England ; and that a suitable estate be purchased in Scotland, as convenient as possible to Edinburgh, for the same purpose. These recommendations would have to be carried out by arrangement between the Commissioners of Woods and Forests and the Board of Agriculture ; and assistance should be looked for from local authorities, societies, and individuals interested in forestry and technical education.

(*b*) That additional facilities for instruction be afforded, by the appointment of a lecturer on forestry in connection with each of the Universities of Cambridge

[1] "17. For effective instruction, however, a large area of woodland for practical demonstration is an absolute necessity."

and Oxford, and that example plots[1] . . . be provided in connection with each of these centres and with Edinburgh.

(*c*) That a good grounding in forestry form an integral part of the curriculum of the colleges providing instruction in Agriculture in Great Britain ; and that short courses of instruction suitable for the requirements of young foresters be also provided there. Instructors should also be available for giving practical advice in connection with the management of woods, the owners of which desire an expert's opinion.

(*d*) That provision be made for the education of foresters and woodmen by employing students to work in both the demonstration forests ; and that suitable buildings be erected on the ground for the instruction and, where necessary, for the accommodation of these student-foresters.

(*e*) That lectures be given, under the auspices of the County Councils, in neighbourhoods where there is a considerable area under wood ; and that scholarships be offered in such counties to enable working foresters to attend courses of lectures.

(*f*) That the inequality shown to exist in the levy of the estate duty on timber be redressed.

(*g*) That the Government be urged to secure the early enactment of a Bill to protect owners of woods against loss by fire caused by sparks from locomotives.

(*h*) That the inquiry conducted in 1895, concerning the area of woodlands, be repeated by the Board of Agriculture, and that details concerning the character of the timber crop grown upon them be ascertained.

(*i*) That the attention of Corporations and Municipalities be drawn to the desirability of planting with trees the catchment areas of their water-supply.

The serious national outlook with regard to coniferous timber is merely hinted at, without any suggestion being made to try and improve prospects by immediate extensive planting. The Committee declared themselves unable to urge Government to form large State forests (see para. 10 below), or to recommend any encouragement being given to private landowners in the way of State loans (para. 33), or even reduction of Local Rates on plantations (para. 28). All the relief they were able to suggest was that irregularity in the incidence of the Estate Duties needs immediate revision (para. 30).

Incomplete though the report be in many important respects, yet the main portions of it are worth quoting :—

6. *Present condition of Forestry.*— . . . It is true that a few scattered efforts have since been made to adopt methodical treatment ; and a wider appreciation of the advantages of close canopy, clean timber, and heavy crops is discernible. Yet, on the whole, there has probably been a further reduction of the already inadequate stock of timber in the wooded area. The more intelligent of our foresters have come to recognise the shortcomings of our practice, and, within the limit of their opportunities, have endeavoured to effect an improvement. . . .

7. *Waste Lands.*— . . . There is in these islands a very large area of waste, heather,

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[1] "15. Even where access may be had to private woods, it is exceedingly desirable that collegiate instruction in forestry should be illustrated by means of example plots. . . . If each plot be of sufficient size, say 3 acres, it is capable not only of demonstrating principles and the effect of mixing and management, but also, within limits, of yielding comparative results. A total area of 100-200 acres at each centre would be necessary and sufficient for this purpose."

and rough pasture, or land out of cultivation, amounting in all to 21 million acres, on a large proportion of which afforestation could be profitably undertaken. . . . Excellent returns, even with indifferent management, have often been obtained from plantations formed on land of little or no value for any other purpose.

9. *Importance of Afforestation.*—The importance of afforestation in the Highlands of Scotland will be readily grasped. Rough land is extensive, capital as a rule scarce, and great woodland areas, where well managed, have proved financially successful, while profits on sheep-farming have of late years reached a very low point. Land under forests would give healthy employment to a much greater number of persons than the same area under sheep. Many hill pastoral farms have one shepherd to three or four thousand acres, but much of such land, for various reasons, is unsuited to the growth of timber for profit. . . . Land quite capable of producing high-class timber employs only one shepherd per thousand acres if used as a sheep-run ; while . . . similar land when under timber gives employment to at least one man per hundred acres, and this without taking account of the labour requisite to remove and work up the timber. . . .

10. *Afforestation of Waste Lands.*— . . . The world is rapidly approaching a shortage, if not actual dearth, in its supply of coniferous timber, which constitutes between 80 and 90 per cent of the total British timber imports. The great area of waste land in these islands which might be afforested . . . thus becomes a matter of grave national concern. No individual effort is likely to cope with such extensive afforestation, not only because British forestry, as now practised, is inefficient, but because of the capital required, the time during which it remains sunk before producing income, and the lack of all security on private estates for continuous good management from the time that the forest is formed until matured timber is placed upon the market. We do not feel justified in urging the Government to embark forthwith upon any general scheme of State Forests under present circumstances ; but the question of planting suitable waste lands under the control of the Crown, or over which the Crown exercises manorial rights, where it may be proved practicable and desirable, is . . . worth the attention of the Commissioners of Woods and Forests.

11. . . . We recommend that the Government department charged with the collection of land statistics should take steps to compile a statement of areas presumably suitable for afforestation in Great Britain.

12. *Existing Woodlands.*— . . . Timber of the kind and quality imported in such large quantities . . . can be grown as well here as anywhere. . . . European "red wood" and "white wood," so highly esteemed for structural purposes, are yielded by the Scots pine and the spruce, two of the commonest trees of British woodlands. That foreign is so generally preferred to home-grown timber is in no way due to unsuitability of soil or climate, but is entirely due to our neglect of sylvicultural principles. It is hardly too much to say that until within the last ten years or so owners of woodlands, with few exceptions, failed to realise that the shape, size, and quality of trees could be influenced by anything that they could do. They seemed to imagine that the character of the final product was largely a matter of accident, whereas it is mainly determined by management. They failed to recognise that cultural treatment which suits oak or ash is unsuited to pine or spruce ; and so it has come to pass that British coniferous timber has been generally excluded by architects from building specifications. As another instance of this, we may refer to the statements supplied by the Post Office as to the unsuitability of home-grown pine for telegraph poles.

14. *University Education.*—It is clear that the same class of instruction is not suitable for . . . all the different grades of persons who have to deal . . . with woodlands. The natural centres for the instruction in forestry of the future owners and agents, under present conditions, are the Universities and provincial Colleges. Here additional facilities for theoretical instruction and practical demonstration are required. . . . We consider that the scope and character of the instruction given at Edinburgh University . . . is the least that should be aimed at, though it might, with advantage, be carried considerably further, and that better facilities should be provided. Similar courses should be provided at Oxford and Cambridge, as well as in all the agricultural colleges, and colleges with agricultural departments, which are subsidised by the Board of Agriculture or by the Scotch Education Department. . . .

16. *State Forest School.*—The desirability of a great State Forest School on the model of Nancy or of Eberswalde has not escaped our attention, but we do not feel justified, under present conditions, in recommending so great an outlay as would be necessitated by the creation of such an institution. We think, however, that many of the advantages of an institution of this type could be secured at a comparatively small outlay by the transference of the Forestry Department at Cooper's Hill to a University centre. . . .

18. . . . No scheme for the general improvement of present conditions can be satisfactory that does not provide for the establishment of at least two large State forests which shall demonstrate the most perfect technical and economic developments of the art of forestry. At present there are no large wooded areas in this country—whether public or private—which foresters and others may visit for the purpose of seeing the working and results of systems that they may think of adopting: they are unable to move along the path of progress because no concrete examples of typical systems are available for inspection. . . . These State forests would also serve as the training-ground for many of our young foresters, whose education will be dealt with later.

22. In England, with its Crown forests, an instruction area could be readily made available with the consent of the State and the co-operation of the Commissioners of Woods and Forests. In Scotland, where the amount of land remaining vested in the Crown is small, an area should be bought, and it would not be unreasonable to ask the State to re-invest in land to the extent of, say, £50,000. We think that, inasmuch as the benefit to landowners to be derived from the instruction and example provided by such a demonstration forest will be very considerable, it would not be too much to expect that they should co-operate by giving a guarantee to the Government for the interest on the purchase-money.

23. . . . Although covering an area somewhat smaller than that indicated above as the minimum desirable, we consider that the Alice Holt Woods could be more readily brought into good working order, and could be made to serve as a useful object-lesson at an earlier date, than any of the other woods belonging to the Crown; and we accordingly recommend that they should be made available as soon as possible to serve as a demonstration area.[1] As regards a locality in Scotland, we are not at present in a position to make any specific recommendation.

24. *Agricultural Colleges.*—With regard to the training of young men who propose to take up land agency as a profession, and who cannot afford to spend three years at a university, we consider that facilities for imparting sound knowledge of the elements of forestry should be provided at the various colleges supplying instruction in agriculture in Great Britain; . . . and we suggest that this subject should receive greater prominence at such institutions, in order that students may qualify themselves to undertake the efficient supervision of what is an important, and should be a profitable, part of many estates.

25. *Training of Foresters and Woodmen.*—For working foresters or woodmen . . . a practical training in the woods naturally forms the best basis of instruction, and for this the State demonstration areas already recommended offer the most suitable medium. But even here . . . manual work must be supplemented by theoretical study. We accordingly recommend that student-foresters be taken on as employés in receipt of regular wages, and that classes be held, which they should be required to attend.

26. In order to provide for the instruction to be given in these demonstration forests, we suggest that the State should equip each of them with buildings, which would offer accommodation for a director and his assistant, and, if necessary, for 10 to 20 student-foresters. We do not anticipate that the cost of the buildings would exceed £5000 to £7500 in each forest. The director should be placed in suitable relationship with the lecturers at the various colleges, and would be responsible for the management of the forest and for the general conduct of the school, and would, at the same time,

[1] The Alice Holt Woods are part of the Crown forests in Hampshire, and have an area of 1906 acres. Although the Committee were fully aware of the exact nature of the improvements and working plans introduced into the Forest of Dean and High-meadow Woods since 1897 by Mr E. Stafford Howard, C.B., the senior Commissioner, and already referred to (on p. 36 above), the report ignored any reference to them.

give instruction in sylviculture and forest management, mensuration and valuation. His assistant would teach the subjects of the growth, structure, and diseases of timber, the formation and properties of soil, and forest entomology. We anticipate that the annual expense of maintenance of each of these schools would be about £750, in which the chief items would be the salaries of the director and his assistant. The classes should be open to young foresters and woodmen selected by County Council Technical Education Committees or otherwise, the normal term of residence being two years. These students would thus work in the woods, and receive systematic instruction. Experience of farm schools shows that young men can be boarded and lodged for 10s. to 15s. per week. . . .

Minor Considerations.

28. *Local Rates.*— . . . In England, the incidence of rates on plantations, and the valuation of woodlands made by Assessment Committees, are subjects of complaint. It has been suggested that, as in some other countries, young plantations should not be rated so long as they yield no return; also that the relief given to agricultural land by the State should be extended to woodland. There are fewer similar complaints from Scotland, although it is interesting to notice that in Scotland a plantation when grazed by stock is rated on its grass rent, the timber bearing no rates; but were the same wood properly managed and stock excluded the timber alone would bear the rates. We are not, however, prepared to make any recommendation on the subject. . . .

29. . . . Claims are made upon timber merchants and others by Local Authorities on account of "extraordinary traffic," it being alleged that the heavy weight of timber damages the roadway. . . . We are of opinion that these claims are unreasonable, more especially in view of the fact that woodlands, by paying rates during the many years when they are yielding nothing, and when no timber is therefore moved along the roads, have contributed to the maintenance of these roads, from which they derive no benefit until the crop is brought to market.

30. *Estate Duties.*—Three systems of levying the Estate Duty on woodlands have already been tried since the introduction of the Finance Act, 1894; and that now in force is peculiarly unfair to the poorer districts. The ordinary rate of duty on agricultural estates rests on a maximum basis of 25 times the annual value of the land, the consequence being that in richer districts where land is valued up to this amount the timber itself bears no duty. In the poorer districts of Britain, however, and in Ireland, where under the Finance Act estates are valued down to sixteen years' purchase, the Death Duty can, where there is a crop of timber to be valued, be levied upon the latter until the maximum is reached; the maximum of twenty-five years' purchase thereby becoming, in those cases where an estate is sufficiently wooded, the minimum basis. It is therefore conceivable that duty calculated on nine years' purchase of an estate could be levied on its timber, which, were the estate more agriculturally prosperous, would be totally exempt. An estate in the comparatively rich lands of Devonshire, for example, might escape a Death Duty upon timber which one in Argyllshire might have to bear to the extent of a fourth of the whole duty raised. Moreover, the pressure of such a Death Duty on timber must both act as a bar to afforestation in districts most needing it, and compel the realisation of immature timber, thus preventing the practice of sound forestry. We feel that this irregularity in the incidence of the duties needs immediate revision.

31. *Damage by Sparks.*—Some adequate security against the raising of fires by sparks from railway-engines seems equally feasible and desirable. . . . It is not necessary to dwell further upon this subject than to urge the desirability of some such Bill becoming law at the earliest opportunity.

32. *Ground-Game.*—The presence of ground-game is ruinous to systematic forestry and to sylviculture by natural regeneration. We think that, in the public interest, the owner of plantations who himself keeps down ground-game should have the right to recover compensation for damage caused by hares and rabbits from adjoining property.

33. *State Loans.*—It has been suggested that the State should advance loans to encourage afforestation. . . . We advise that the State should concentrate any efforts it may make upon the provision of adequate facilities for instruction. Once adequate provision for training is made, and the consequent improvement of our present woodlands

becomes manifest, it will then be opportune to raise the subject either of loans or of State forests. . . .

35. . . . To prevent all risk of the contamination of the water-supply, it is at the present day the policy to remove, as far as possible, all human habitations and farm buildings, as well as live-stock, from such areas. These areas, therefore, however well suited they may otherwise be for the production of crops or the maintenance of live-stock, are practically derelict, and yield no return, beyond that obtained from the sale of the water upon what is usually a very heavy capital expenditure on the part of the Corporation. We desire, therefore, to draw the attention of Corporations to the advantages and profits to be derived from planting their catchment areas with trees, which ultimately will not only contribute materially to the retention of the rain that falls over the area, and thus assist in regulating the water-supply, and in preventing floods and water-famines, but will tend to the purification of the water, and should also, properly managed, yield a fair and regular income. . . .

Up to the present, on the part of the State, the practical outcome of the Committee's recommendations has been that the Commissioners of Woods and Forests have taken steps on a small scale for the instruction of woodmen in the Forest of Dean, the men each week working on four days and receiving instruction on two days; while the Board of Agriculture and Fisheries has made two grants, each of £250 per annum, for the establishment of Lectureships in Forestry at the Durham College of Science (Newcastle-on-Tyne) and the University College of Bangor, in North Wales.

Private enterprise has at the same time inaugurated a Chair of Forestry and Estate Management at the Royal Agricultural College, Cirencester, to which Earl Bathurst's adjacent woods have been made available for educational purposes; while a Lecturer on Forestry has also been appointed at the S.E. Agricultural College at Wye, in Kent. Forestry is also to a certain extent taught at the East of Scotland Agricultural College, Edinburgh, and the West of Scotland Agricultural College, Glasgow (see also p. 35).

A new departure in State policy has also been instituted with regard to woodlands in Ireland. Under section 4 of the *Irish Land Act*, 1903, powers were given for enabling Government to make arrangements for "the planting of trees, or the preservation of . . . woods or plantations," and for retaining in their own hands woodlands and waste lands suitable for planting on estates acquired by purchase under the Act. And as a first step towards the improvement of Forestry in Ireland, and perhaps also towards the formation of extensive plantations, the Department of Agriculture and Technical Instruction has acquired the Avondale estate (Rathdrum, County Wicklow, formerly the residence of the late Mr C. S. Parnell, M.P.) and the adjoining Ballyfad woods as the nucleus for a Practical School of Forestry.

CHAPTER II.

CONCERNING THE PRESENT EXTENT AND CONDITION OF THE WOODLANDS, AND OF TECHNICAL EDUCATION IN FORESTRY, THROUGHOUT GREAT BRITAIN AND IRELAND.

According to the latest available Agricultural Returns for Great Britain (1895) and Ireland (1902), the area of lands classifiable as "Woods and Plantations" is 3,029,139 acres, or 4733 square miles, the land statistics being as follows (in acres):—

	Area.			Woods and plantations.	Mountain and heath-land.	Percentage.	
	Land.	Water.	Total.			Wood-land.	Waste land.
England . .	32,381,051	169,647	32,550,698	1,665,741	2,305,823	5·1	7·1
Scotland . .	19,069,010	389,460	19,458,470	878,765	9,374,512	4·5	48·1
Wales . . .	4,748,109	28,670	4,776,779	181,610	1,250,813	3·8	26·2
Total for Great Britain	56,198,170	587,777	56,785,947	2,726,116	12,931,148	4·8	22·7
Ireland . . .	19,322,798	1,027,927*	20,350,725	303,023	3,779,640	1·5	18·5
Total for United Kingdom	75,520,968	1,615,704	77,136,672	3,029,139	16,710,788	3·9	21·6

* This includes water, roads, fences, &c., part of which are, of course, land.

These statistics show that the United Kingdom is the most poorly wooded country in Europe, and that, in proportion to its area, Ireland, with a general average of only 1·5 per cent of woods—while the uncultivated areas, aggregating 23·6 per cent, include 18·5 per cent of turf, bog, marsh, and barren mountain-land, and 5·1 per cent of water, roads, fences, &c.—is probably the most poorly wooded country in the whole world.

It is not possible, from the statistical data available, to form any estimate of what these woodlands may have cost to plant, or what may possibly now be their annual yield in timber or their actual market value. Nor would it under any circumstances be possible to determine what annual income they might perhaps, under improved management, be made to give in the form of timber, because a very large proportion of the lands classed as "Woods and Plantations" are either maintained chiefly as game-coverts, or else merely form ornamental portions of large estates, and act as shelter-belts to residences and agricultural lands.

The poverty of the United Kingdom with regard to woodlands will be seen from the table below[1] relating to the other countries in Europe. The extreme disadvantage of this country in respect to timber becomes all the more apparent when it is recollected that by far the greater portion of our woods are primarily intended for sport, ornament, and shelter. They were neither formed, nor are they maintained, for the growing of timber for profit :—

Country.	Woodland area.	Percentage of country that is woodland.	Woodland area per head of population.	Percentage of woodlands owned by				
				State and Crown.	Private land-owners.	Church lands and other endowments.	Municipalities and village communities.	Corporations.
	acres.		acres.					
Russia	447,592,405	36·0	4·58	60·3	29·7	...	...	...
Finland	50,359,471	38·0	25·77	71·1	18·9	...	...	...
Sweden	45,061,984	44·4	9·36	19·9	80·1	...	...	...
Norway	19,280,820	24·0	10·56	12·5	84·8	2·7	...	...
Austria	24,150,215	32·6	1·00	6·5	71·3	7·1	14·9	0·2
Hungary	22,683,469	28·3	1·27	16·0	41·3	6·6	18·5	17·7
Germany (including Luxemburg)	34,734,123	25·8	0·66	32·9	47·5	1·3	15·6	2·3
France	23,360,062	17·7	0·56	11·1	66·5	22·5	...	...
Spain	20,955,480	17·0	1·27	82·2	17·8	...	...	...
Turkey (with Bulgaria)	13,919,685	22·2	3·50	...	...	...	...	...
Bosnia and Herzegovina	6,583,515							
Italy	9,030,320	12·0	0·32	3·8	53·8	43·0	...	...
Roumania	6,796,417	23·0	1·25	41·7	53·7	4·6	...	...
Great Britain and Ireland	**3,029,139**	**3·9**	**0·07**	**2·3**	**97·7**	...	...	...
Servia	2,393,430	20·0	1·43	...	...	...	...	...
Switzerland	2,032,572	19·9	0·69	...	...	...	...	...
Greece	2,025,400	15·8	1·20	80·0	20·0	...	...	...
Belgium	1,205,830	16·6	0·10	...	...	...	...	...
Portugal	1,165,346	5·1	0·25	...	...	...	...	...
Holland	568,100	7·0	0·10	...	...	...	...	...
Denmark	508,298	5·4	0·25	...	...	...	...	...
Total	737,436,081	30·2	2·50	...	...	...	...	...

[1] Compiled from Endres' article on *Forsten*, in *Handwörterbuch der Staatswissenschaften*, Jena, 1892, and Weber's *Die Aufgaben der Forstwirthschaft*, in Lorey's *Handbuch der Forstwissenschaft*, 2nd edit., 1903, vol. i. pp. 16-19; but with corrected figures for Great Britain and Ireland.

In consequence of its poverty in woodlands, its dense population, and its vast commercial industries, Great Britain requires immense quantities of timber each year; and as it produces comparatively little clean, useful timber of home growth, its necessities have to be supplied by importing wood from other parts of the British empire and from foreign countries. So large are the British timber imports that they form one of the chief factors in determining the level of prices in Europe. In spite of the more extensive use of substitutes, such as iron beams and joists, cement, &c., in the building trade, the British timber imports are, owing to the increase in the population and the expansion of industries, continually increasing in quantity. And at the same time they are also ever gradually increasing in monetary value, because the only way the present demands for timber in the chief countries of Europe and in the United States of America can now be met, is by opening up fresh tracts from which extraction has not hitherto been profitable.

Simultaneously with this expansion in our requirements, the sources of supply are diminishing as the natural forests in thinly populated countries are being cleared for permanent cultivation. Land-locked areas still forest-clad are workable only when the price of timber more than covers the cost of felling, transport, handling, &c., so as to leave a profit on its extraction for sale. But there are limits to such, as yet untapped, sources of future supply in the world; and the time is probably comparatively near at hand when there will be such a competition for timber among the most densely populated countries that extensive plantations may perhaps once again become very profitable portions of landed estates, as they were about a hundred years ago. Indeed, it is likely that this appreciation in value will begin to set in within the course of the next thirty years. Of hardwoods there is never likely to be lack, for many parts of our empire can furnish vast quantities of fine hardwoods for which no profitable market yet exists; but with regard to Conifers this is not the case. The natural supplies of the Pine and Fir tribes are limited and ever decreasing; while the demands for such wood are already vast, and are ever increasing.

Our average imports of hewn and split timber for the three years 1890 to 1892 amounted to 7,083,388 loads, valued at £15,357,119, or 43s. per load; by 1900 they had increased to 9,899,142 loads, valued at £25,870,934, or 52s. 3d. per load. These figures speak for themselves. But at the same time, the actual facts known regarding the existing supplies of coniferous timber (forming about nine-tenths of our imports) throughout the world's workable forest areas justify very serious apprehension as to the still wooded tracts being able to supply even the present demands continuously, let alone the gradually increasing requirements, which must also be taken into consideration. These facts may be briefly stated as follows:—

In former times the growth of Oak was encouraged in view of the necessities of the navy, but with the substitution of iron for timber, &c., of late years, the need for hardwoods has become less pressing. Great quantities of Teak, &c., are now imported, and with regard to these particular classes of hardwoods, neither the present nor the future condition of the forests in Britain will exert much influence upon the market demand; and it is probable that increased supplies, not yet remunerative, will become available in the future.

It is otherwise with the light woods. Of the total imports of £25,378,000 for timber and other tree products in 1899, we spent about £18,000,000 on coniferous wood alone, which could easily and profitably be grown at home. And these imports have increased of late years. The two great sources of supply of coniferous wood are the Baltic countries and Canada; and the demands of industrial countries, especially of Germany in the case of the first-named, and of the United States in the second, will absorb a very large proportion of their available surplus. Canada uses about £16,000,000 worth of timber per annum, the value of the wood products exported being £5,000,000 to £6,000,000. The United States cannot meet its own requirements of timber, and the growth of industries, more especially the extraordinary development of the manufacture of wood-pulp, must make very heavy demands on the Canadian supplies in future.

These circumstances render a rise in the price of timber certain, and the days of cheap timber in Great Britain are almost at an end. Britain's requirements cannot be entirely met at home: even if the 3,000,000 acres of woodlands were trebled, and were in a fully stocked condition, they would only just supply existing needs, without leaving any margin for expansion of industries. And, with few exceptions, British woods are neither fully stocked nor well managed. There have been of late, however, some hopeful signs that landowners are awakening to the fact that their woods might be improved, and several have had working plans drawn up by experts. For the proper management of woods, and a regular revenue, a working plan is essential.[1]

Despite the use of various substitutes for constructive purposes, the President of the Institute of Civil Engineers felt obliged in his presidential address in the autumn of 1902 to sound the note of alarm regarding the future outlook for this indispensable commodity. The well-known facts of the matter are that the outlook is growing darker and darker, and that, unless we can make advantageous imperial arrangements with Canada, the cost of coniferous timber in the very near future will increase even more rapidly than has recently been the case.

When it is considered that almost exactly nine-tenths in value, and over nine-tenths in quantity, of our present imports of wood consist of Pine and Fir timber capable of being grown at home, and that nearly three-fourths of this coniferous wood in quantity, and more than four-fifths in value, are imported as sawn or split, &c., it will of course be seen that, if we tried to grow our own supplies of wood, very large sums would be distributed among various industrial classes in addition to the large labour bills that would be payable in the woodlands themselves. Hence it is obvious that, in the economic interests of Britain, the formation of plantations of pines and firs is desirable, on the most extensive scale that seems feasible and profitable; because there is little hope now that we can find a way out of our difficulties, as on previous occasions, by discovering substitutes or by tapping fresh storehouses of cheap and easily transportable timber. On the contrary, the history of the wood-pulp industry makes it far more probable that the world's demands for timber will be ever increasing, while the sources of supply will be constantly diminishing.[2]

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[1] Nisbet, in *Trans. Roy. Scot. Arbor. Socy.*, 1900. Vol. xvi., part iii. (1900) and vol. xvii., part ii. (1904) contain several articles giving details regarding timber imports, sources of supply, and our growing requirements. The most exhaustive is Schlich's paper on *The Outlook of the World's Timber Supply* (vol. xvi., part iii., p. 355), reprinted from the *Journal of the Society of Arts*, 1st March 1901.

[2] *Quarterly Review*, July 1903, No. 395, p. 94.

By far the greatest part of the 3,029,139 acres, or 4733 square miles, of woods and plantations in Great Britain consists of old copse-woods.[1] Most of the standard trees in these copses are Oaks dating from the time when Britain's existence as a great Power was dependent on home-grown timber supplies. These standard Oaks are mostly rugged trees with short boles and large limbs, in consequence of the wide-branching growth formerly encouraged for the express purpose of providing curved and crooked timber for ship-building. Somewhat similar treatment was also applied to Pine, Larch, and Fir plantations; and most of these, ranging up to about seventy to ninety years of age, exhibit the natural defects due to this national form of arboriculture followed from time immemorial. In the case of woods already middle-aged or approaching maturity, little or nothing can now be done for their improvement; but when, in course of time, it may be thought expedient to fell and realise them, attention may then be given to their replantation on business principles. In other cases, underplanting may often improve them, if it can be shown to be likely to prove profitable under the given circumstances; but in young plantations past errors may often still be corrected by exercising greater caution with regard to future thinnings.

In consequence of free trade and the abolition of the timber import duty, there has been a great fall in the value of home-grown timber and coppice-wood; and this, combined with the growing scarcity and cost of suitable labour in rural districts, has resulted in much of the method having fallen into disuse that formerly existed in dealing with copses. In many parts of the United Kingdom Forestry has thus become almost a lost art. That it was different in olden times is clear from Evelyn's *Sylva.* And from the details about woodlands and their management given in the histories of Agriculture compiled (about 1800-1815) for many counties on behalf of the Board of Agriculture by Young, Stevenson, Driver, and others, it seems that down till then there was far more of method and regularity in the selection of standards and the working of the coppice than has been habitual in any part of the kingdom during the last fifty years. As a result of this, most English copses are irregularly stored with standards; and another result seems to have been that the best of the trees have usually been cut and sold, because one cannot help being struck by the evident fact that often only inferior trees have been left, while the underwoods are patchy and uncared for. In many cases, too, the coppices have to a greater or less extent been destroyed by ground game, or have, through sheer neglect, been allowed to revert and become a tangled mass of weeds like blackberry and bracken.

[1] No returns are available for Great Britain, but the Statistical Returns for Ireland in 1902 show that the total woodland area of 303,023 acres was estimated to consist of 153,899 acres under mixed trees, 45,033 under Larch, 32,998 under Fir, 14,976 under Spruce, 2494 under Pine, 26,611 under Oak, 6987 under Ash, 10,095 under Beech, 2519 under Scyamore, 2709 under Elm, and 4702 under other trees. But any such definite return must only be accepted merely as a rough generalisation; because, as a matter of fact, the great bulk of the plantations formed during the last fifty or sixty years have been of Conifers in which the Larch has usually predominated, while in the remnants of the ancient woods Oak is still undoubtedly the chief tree.

The existing woods and plantations in Great Britain and Ireland may be roughly classified as under :—

I. *Remains of the original woods and old plantations—*
   1. Demesne woods and ornamental plantations, usually in the form of shelter-belts near the residence on large estates.
   2. Old Oak copse-woods or coppice under standards, the remnants of those formerly worked for timber.
   3. Old Oak coppices formerly worked for bark, and now usually either (1) interplanted with Conifers, or else (2) forming Scrub Oak woods, much neglected and intermixed with self-sown Birch, Alder, Willow, &c.

II. *Plantations formed during the last fifty to sixty years—*
   4. Plantations, usually of coniferous trees, made for the express purpose of forming game-coverts or else to act as shelter-belts, and managed chiefly for the preservation of game.
   5. Plantations of Larch, Pine, and Fir formed on poor land, and mainly with a view to profit.

In the absence of official data, it is not possible to make any reliable estimate about the relative area or proportion of each of these five main classes of woodlands; but probably not more than one-fourth to one-third of the existing woods and plantations can be said to be intended to be primarily worked for profit. And it may be added that there is seldom any reasonable attempt made to secure good results and continuity in management by the adoption of a well-considered working plan or scheme of management. It seems to be the exception, and not the rule, to have any definite line of action for continuing work from year to year. And seldom indeed, even on large wooded estates, have I ever found the landowner, or his agent, or his bailiff or forester, able to inform me offhand as to the exact acreage of any given wood or plantation, or even of the total acreage for the estate, or to give such details as to revenue and expenditure, cost of planting, &c., as might be expected from those intimately concerned with the working of the woods. There being no regular scheme of management, the various works of thinning, clearing, and replanting are consequently usually undertaken in a sporadic and more or less haphazard way, so that there can be nothing like definite continuity in the operations.

The demesne woods are generally in the immediate vicinity of large residences, and are of a more or less ornamental character. Here one often finds splendid growth of Oak, Ash, Beech, Elm, Larch, Scots Pine, Douglas Fir, Silver Fir, Spruce, and the various other kinds of trees, some of which have attained unusually large and fine dimensions. The size and beauty of many of these ornamental trees are often so striking as at once to show the fallacy of the assertion sometimes made that timber trees will not grow as well in the climate of the United Kingdom as in that of the Continent of Europe. Many of these demesne woods appear to have been considerably added to from about 70 to 120 years ago by the formation of broad shelter-belts, to screen the residence and the home-park and adjoining grazing fields from cutting winds. In woods of this class the removal of timber usually extends, of course, only to windfalls or to over-mature and diseased trees requiring to be thinned out. Many of such woods are now thin from age, and are consequently far less effective as shelter-belts than they once were, when the trees (being younger, more shade-enduring, and more energetic in leaf-production) stood thicker and formed a closer cover.

The Copse-woods, or Coppice under Standards, the national form of Arboriculture, and especially typical of the warmer portions of England, have for the most part become practically transformed into game-coverts—or, at any rate, any management as to timber-growing is usually strictly limited to the condition that ground-cover must be provided for game, and this, of course, makes rational Forestry impossible. Yet the copse-woods and coppices were at one time among the most profitable parts of large estates. This is well shown in Stevenson's *Agriculture of Surrey*, 1813 (pp. 416-438), which gives a fair idea of the way copse-woods were managed before this branch of Forestry became a lost art in England (see also Part III., *Sylviculture*, chap. vi.) :—

Copse-woods.—These consist principally of the oak, birch, ash, chestnut, sallow, hazel, and alder. . . .

Age of cutting.—The value of underwood has risen so much lately that this circumstance alone, even if no other operated to the same end, would naturally cause the underwood to be cut down before its proper season. To this may be added, that where a farm is held under a lease for twenty-one years, possessed of any great extent of coppice, the farmer is tempted to get two cuttings during the tenancy of his lease, even though neither of them afford much profit, and though by this method he is not doing justice to his landlord or his successor.

Perhaps the greater part of the copse-wood in the Weald of Surrey is cut between nine and ten years : this, however, is allowed to be much too early. Taking the different kinds of soil, or rather the only varieties that exist in this part of Surrey, the paler and moister, and the darker and drier clays, and the different kinds of wood which usually form the coppice, fourteen years are considered necessary to bring them to a proper size ; and this period is allowed for the growth, where no temptation leads to a premature cutting.

Rent.—This is generally regulated by the rent of the corn-land in the neighbourhood ; or more properly speaking, copse-wood, though the returns from it are but seldom, yet as it requires, or at least receives, little or no labour, and is exposed to few accidents, is taken at the same rent as the other parts of the farm, where it forms part of a farm, or where it is taken by itself at the average rent of the district. . . . The most common rent of copse-woods in the Weald is from 12s. to 16s. per acre ; in the other parts of Surrey, which are not affected by their very immediate vicinity to London, the rent may rise from 15s. to 20s. per acre.

Produce.—In the neighbourhood of such a city as London, and in a county where there is so great a demand for fuel, both for domestic purposes and for the forge, the brick-kiln, and the lime-kiln, not the smallest nor the most trifling part of the underwood is useless or without its value. . . .

The value of all kinds of timber on the ground, particularly oak, has been increasing within these last twenty years more rapidly and in a greater proportion than most other agricultural products. This seems to have arisen from an increase of demand both for the wood and bark, unaccompanied with the prospect of an adequate supply after the trees now on the ground are felled. . . . At present the price of oak standing will run, according to its quality and measurement, from £10 to £13 per load. In 1798, large oak timber in the Weald was £5 per load; in 1803 it had increased in price to £9.

That was a very different state of affairs from what now exists throughout most of the United Kingdom. Iron-fencing and wire-netting have ousted wooden hurdles, and stout posts with overhead wires have taken the place of hop-poles. The description given of the copses in Hampshire (*Victoria County History*, vol. ii. p. 467) applies more or less to nearly all the old woodlands throughout southern and central England:—

> At one time the underwood used to realise from £8 to £10 per acre, but it now fetches only from £2 to £5. The increase permitted in the number of rabbits has been the cause of great injury both to the timber and the underwood, and at the present time the woods are of more value for sporting purposes than anything else. (Earl of Northbrook's Stratton estate.)
>
> The coppice now fetches only from £4 to £5 an acre, whereas formerly it usually sold at from £10 to £15 an acre. Barking of oak, once a remunerative operation, now hardly pays at present rates. (Earl of Selborne's Blackmoor estate.)

Indeed, it is sometimes even worse than this. The Earl of Harrowby, presiding on 25th February 1904 at a lecture on Forestry at Carpenters' Hall (London), said that—

> I know from experience how difficult it is to get an agent or a woodman who knows anything about Forestry or understands the work. . . . There is very little real Forestry now, such as there was a hundred years ago. In Gloucestershire I have a wood of 200 acres, which was planted some time ago with underwood and gave a handsome return. Fifteen or twenty years ago 20 acres produced £7 an acre, but only last winter I had great difficulty in persuading a timber-merchant to give 15s. an acre.

The Oak-bark industry has, however, gone under many years ago, along with the favourable market for Oak timber for shipbuilding and of any considerable or remunerative demand for fuel and Oak of small dimensions. When these sources of income became unremunerative, many landowners appear simply to have cleared their Oak-woods of all marketable trees and left the whole of the old crops to renew themselves from stool-shoots thrown up from the stumps of the trees and of the coppice-poles. Other landowners, especially in Ireland, interplanted Larch and Scots Pine among the Oak-stools—most likely to "nurse" the young Oak, as used to be the old idea; and in such cases the Larch, having favourable conditions, grew into fine healthy trees with sound timber. The Oak stems in stool-shoot highwoods of this class transformed from coppices often only girth from about 30 to 36 in. (at breast-height) at fifty to sixty years of age, and but rarely attain a girth of over 5 ft. on the better qualities of land. Numerous borings made by me (in S.E. Ireland) to ascertain the rate of growth of such coppice-grown poles and small trees showed that it had often taken them from eighteen to twenty-four years to increase by the last inch of radius or 6 in. of girth (measured at breast-height).

Oak-woods of the copse and coppice classes, and highwoods grown from coppice-shoots, are no longer remunerative, and are never again likely to become profitable. But they are usually suitable for turning into mixed Conifer crops, which are those most likely to prove profitable on the poorer classes of land in the future. In Ireland, however, many of these poor Oak-woods are stocked (and often very thinly stocked, too) with poles and small trees of a size for which no profitable market exists at present; and unless the present poor crops can be disposed of advantageously, the landowners can have neither means nor desire to form any new plantations, which would tie up capital without giving any tangible return for many years to come. There are many thousands of acres of poor scrubby Oak-woods of this description, once sources of considerable profit, which have now long since failed to yield any annual revenue, owing to there being no local industries requiring such wood as its raw material.

In sample plots counted to ascertain the crop in such woods, I have found an acre of 50- to 55-year-old Oak contain 302 Oak and 2 Birch, varying from 15 to 38 in. in girth at breast-height, and another similar wood, with a different aspect and 60 to 65 years old, had 240 Oak and 8 Ash, varying from 12 to 50 in. in girth. In the former case the stems are 12 ft. apart on the average, and in the latter 13 ft., the true average girth at breast-height being 28 and 34 in. respectively. In the first case the cubic contents were found (by estimate) to be 2567 cb. ft., or about 50 cb. ft. per acre per annum, and in the latter 2520 cb. ft., or about 40 cb. ft. per acre per annum. It is splendidly hard wood, yet the owners would probably be glad to sell the whole crops at 6d. a cubic foot. Again, in other two woods of this same class, and now 60 to 65 years of age, there were respectively 110 Oak and 136 Oak and 8 Birch per acre, ranging from 22 to 55 in., and from 28 to 55, with a true mean girth of 40 and 39 in. at breast-height, the average distance from stem to stem being 19 and 17 ft., which showed clearly that the crop on the ground is far too thin to be profitable at that age and size of stem.

With regard to Conifer plantations made from twenty to sixty years ago, and by far the most important as regards the production of timber, I have seldom seen young crops of even twenty-five to thirty years of age which have not been already more or less damaged by premature and unnecessarily heavy thinning—if one considers the chief aim of Forestry to be the production of the largest possible crop per acre of timber of the best possible quality. This purely economic view of Forestry, which is general throughout France and Germany, has not, however, hitherto found acceptance among our landowners, because special considerations usually obtain as to game preservation and ornamental effect, which in most cases can hardly fail to render the woodlands unprofitable. This depreciates both the value of the timber crop and of the land (reckoned on its revenue production); but that is entirely the landowner's concern.

In order to ascertain the true existing condition and the actual present cubic contents and value of this important class of plantations, numerous measurements of specially selected sample areas were recently (1903) made by me in the S.E. of Ireland. The results of the measurements in ten typical plantations, varying from twenty to fifty-four years of age, are here given as likely to be of general interest. And it should be added that, in each of these ten cases, the sample area was *in one of the best portions of the plantation*, so that the estimates represent considerably better results than the general average condition of the woodlands. It will, of course, be at once apparent that the growing-stock in each of these cases is only from one-half to two-thirds of what it might possibly have been (see *Management of Woodlands*, in vol. ii., Part II.), if the plantations had been treated in the best way to effect the main object of producing the largest amount of timber

	Locality.	Age.	No. of stems per acre.			Girth (at breast-height) ranging from	The true average stem was found to have—					
			Larch.	Scots Pine.	Total.		Girth.		Total length.		Timber length (to 6 in. diameter).	
							Larch.	Scots Pine.	Larch.	Scots Pine.	Larch.	Scots Pine.
		years.				inches.	inches.	inches.	feet.	feet.	feet.	feet.
1	Co. Wicklow.	20	92	526 and 66 Spruce	684	10-34	...	19	...	...	...	...
2	Co. Waterford*	30	658	2 Spruce	660	10-40	23	...	59	...	26	...
3	Co. Waterford	32	234	227 and 8 Oak	469	10-34	24	23	60	57	30	32
4	Co. Waterford*	33	326	14 14 Spruce 6 Ash	360	10-40	25	...	59½	.	32	...
5	Co. Waterford	30-33	682	182	864	10-37	21	27	46	38	18	20
6	Co. Wicklow .	33	554	94	648	13-38	22	31	46	50½	22	30
7	Co. Wicklow .	34	250	122	372	16-49	33	28	58	...	38	...
8	Co. Wicklow†	37	840	14 Oak	854	10-40	20	...	45	...	16	...
9	Co. Wicklow .	38	344	71 20 Spruce 3 Oak	438	10-46	26	...	46	...	19	...
10	Co. Wicklow .	54	233	90	323	15-46	29	34	57	53	32	40

* Allowing for three years' difference in age, these two plantations are as nearly alike as one can well about 300 stems per acre, or not very far from one-third of the cubic contents in timber per acre. This is more

† An adjoining Larch plantation of twenty-six years of age, with similar soil and aspect, showed 1238 distance of a little over 6 ft. from stem to stem.

Note.—The above growing-stock (in one of the *best* parts of each plantation) varies from only about one-half The great differences shown in the above table give some idea of how unsatisfactory the formation of

The true average stem was found to have—				Marketable contents per acre.			Estimated value of standing crop per acre *in situ*.	Average growing space per tree.	Average distance from stem to stem.	Remarks as to soil and situation.
Length (to 3 in. diameter).		Marketable contents.		Larch.	Scots Pine.	Total.				
Larch.	Scots Pine.	Larch.	Scots Pine.							
feet.	feet.	cb. ft.	cb. ft.	cb. ft.	cb. ft.	cb. ft.		sq. ft.	feet.	
...	...	...	...	...	...	...	...	63·6	8	*Soil* poor, resting on clay slate. *Aspect*, north. No sample stem could be felled.
46½	...	5·16	...	3394	11 Spruce	3405	£60	66	8	*Soil*, a good loam. *Aspect*, north; position sheltered. *Crop* tall and well-grown, but somewhat thin, and it is now practically mature.
51	44	5·66	6·18	1324	1402	2726 (plus 8 Oak)	£50	93	9·6	*Soil*, a light loam, with stony subsoil. *Aspect*, north. *Crop* has recently been rather heavily thinned.
49	...	6·89	...	2246	234	2480	£45	120	11	*Soil*, a good loam, subsoil gravelly. *Aspect*, east. *Crop* has recently been heavily thinned.
...	...	2·53	3·47	1725 (plus tops below 6 in. diameter)	631	2356	£50	50	7	*Soil* good, with stony subsoil. *Aspect*, east.
39	38	5·48	9·5	3036	893	3929	£57	67	8	*Soil* mostly shallow, resting on clay slate and mica schist, and interspersed with granite boulders. *Aspect*, west. *Crop* would have been heavier, but for removal of best poles between fifteen and twenty-four years of age. *Crop* is now practically mature.
(not measured)		10·33 (plus tops below 6 in. diameter)	...	2583 (plus tops below 6 in. diameter)	(not estimated)		£50	117	10·8	*Soil* loamy, lying between large granite boulders. *Aspect*, north-east, on steep hillside. *Elevation* about 600 ft.
(not measured)		2·84 (plus top-end below 6 in. diameter)	...	2385 (plus tops below 6 in. diameter)	...	2415 (plus top pieces)	£100	51	7	*Soil* light, resting on clay slate. *Aspect*, south-west, on a steep slope. The disposal of timber is here favourable.
(not measured)		2·11 (plus top)	...	726 (plus tops)	(not estimated)			97	10	*Soil*, a good loam, though somewhat peaty. *Aspect*, south. *Elevation* about 700 ft.
49	47	8·55	10·79	1996	971	2967	£68	135	11·6	*Soil*, a good loam, here on almost level ground or on a very gentle slope. *Aspect*, south by south-east; sheltered, at an *elevation* of about 700 ft. *Crop* is fully mature.

obtain for the purpose of comparison. A recent heavy thinning in No. 4 appears, therefore, to have removed
than a thinning: it really is a partial clearance of the crop.
stems per acre, ranging from 10 to 25 in. in girth at breast-height, and averaging 15 in. This gives an average

to two-thirds of what it might have been in each case with better sylvicultural treatment of the plantations.
Average Yield Tables would be likely to prove in Britain.

per acre. Their condition amply justifies the astonishment of foreign foresters, such as Boppe and Schwappach[1] (see pp. 52, 53).

Other five sample areas of interest, also measured in Co. Waterford, may likewise be summarised. They deal with the best parts of plantations treated more for ornament than with a view to profit, and which are already over-mature in consequence of unnecessarily heavy thinnings (see p. 55).

Even these few data convey suggestive information. Those in the first table, referring to mixed Conifer plantations made on poor land with a view to profit, show the results of what the owners or agents have believed to be the proper principles of Forestry. But these plantations have all been more or less over-thinned, and in consequence of this (1) they have recently suffered much greater damage from wind than would probably otherwise have been the case; and (2) the total cubic contents of their timber crops are smaller (though the individual trees are larger in girth) than if the average distance from stem to stem were less, while still sufficient to allow for the physiological requirements of the trees. This at once touches the question of thinning,—the weakest point in British Forestry,—which will be dealt with subsequently (see Part III., *Sylviculture*, chap. v.)

Apart from the general results of premature and unnecessary thinning, there is, however, one particular and very important result which may here be mentioned—viz., it often reduces the profitable rotation to about 35 to 40 years in the case of Larch and Scots Pine plantations. Even allowing for the more rapid thickening of girth in the lower half of the stem, there can be no doubt that a much larger quantity and a better quality of timber would be produced with a closer canopy and a longer rotation. There is no climatic reason why our coniferous woods should not be workable with profit with a rotation of at least 40 to 50 years in general, and 50 to 60 or even 60 to 70 years on more favourable soil and situation, for the production of the larger dimensions of timber,—though this, of course, is entirely the duty of the State, and not of any private landowner.

While it is on every hand admitted that the British woodlands are generally in a very unsatisfactory condition, it would in some ways be matter for surprise if affairs were otherwise. It is one of the characteristics of our system of government by political parties that legislation seldom takes place on anything like the "paternal" lines usually adopted in other countries. So far as Forestry or Arboriculture has been concerned, the result of this characteristic has been that whenever the pressure of immediate national demands for shipbuilding timber became relieved by our supremacy at sea and by the use of iron and steam in communications, the question of growing timber in Great Britain and Ireland failed to be of any further weight with either political party, and it was therefore neglected entirely. No provision being made for technical instruction, there was naturally retrogression instead

[1] "In Britain, thinnings, especially in the younger woods, are conducted with rash severity. This is done partly to encourage the remaining trees to increased growth, but chiefly out of regard to the interests of game."—Schwappach, in *Trans. Roy. Scot. Arbor. Socy.*, vol. xvii., part ii., 1904, p. 174.

	Locality.	Age.	No. of stems per acre.				Girth ranging from	The true average stem was found to have—						Remarks as to soil and situation.
			Larch.	Pine.	Other trees.	Total.		Girth at breast-height.	Total length.	Timber length.	Marketable contents.	Average growing space.	Average distance apart.	
		years.					inches.	inches.	feet.	feet.	cubic feet.	sq. feet.	feet.	
1	Co. Waterford .	40-42	286	...	...	286	22-43	32	69	45	10·3 (plus top below 6 in. diameter)	152	12·3	*Soil*, moist peaty loam. *Aspect*, north. *Stock* already so thin as hardly to be called a crop. This was a pure Larch plantation.
2	Do. .	40-45	266	90	12 Oak	368	22-49	33	68	47	13 (plus top-end below 6 in. diameter)	236	15·3	*Soil*, a light loam, with stony subsoil. *Aspect*, south, exposed.
3	Do. .	45-50	250	33	28 Oak	311	13-52	31	68	41	9·4 (plus top-end below 6 in.)	140	12	*Soil*, a good loam. *Aspect*, south, exposed.
4	Do. .	55-60	318	...	...	318	22-40	31	69	41	10·25 (plus top-end below 6 in.)	136	11·6	*Soil*, light and stony. *Aspect*, east, but sheltered.
5	Do. .	60	162	20	...	182	22-55	32	70	48	14 (plus top-end below 6 in.)	239	15·4	*Soil*, a good loam. *Aspect*, north-east.
6	Do. .	65	...	...	...	...	...	...	...	...	...	...	...	Plantation on a gentle slope, with northern aspect.
	(*a*) In best part	...	183	51	...	234	Larch, 22-49 Pine, 25-55	Larch, 31	71	50	13·5 (plus top-end below 6 in.)	186	13·6	
	(*b*) In thin, open part	...	134	88	...	222	Larch, 22-43 Pine, 25-55	30	...	...		392	19	

Note.—These crops only represent from one-third to one-half of what might have been grown on the above lands.

of progress. And as, at the same time, the wealth of the landowning classes increased steadily till about 1875, the woodlands, no longer yielding such good returns as they once did, were more and more given up to game preservation, sport, and ornament. This tendency became all the more rapid when cheap foreign timber acquired the market so completely that the smaller sizes of home-grown wood gradually sank lower and lower in value. And now, when many a once prosperous landowner finds himself forced to sell or let his estate, the rich commercial men who usually acquire temporary or permanent possession want woods for sport and ornament, not for growing timber for profit. The sporting rent obtainable, even for poor land on which a large stock of rabbits has been allowed to increase, is often better than the agricultural rent; and wherever rabbits are allowed to become numerous in woodlands, profitable Forestry is out of the question.

The intensely conservative human instinct also makes itself more felt in Britain as regards trees and woods than with regard to anything else connected with an estate. The landowner who has seen the trees grow up, which his father or grandfather planted, and which he has been familiar with all his life long, naturally feels an instinctive dislike to cut his woods, unless compelled to do so through urgent need of ready money. And still stronger, of course, is this conservative instinct with regard to older trees, even though they may have reached their full maturity, and can only lose in value if allowed to stand any longer. Old Oaks of 150 or 200 years can be felled in half an hour. So long as they stand, the owner can always change his mind and order them to be felled; but once down, no amount of money can replace them. And even if the landowner himself should be of an unsentimental, matter-of-fact turn of mind, his wife and daughters are almost sure to plead for the sparing of timber-trees not growing in outlying and distant woods. This strong feminine influence is often even exercised successfully in the protection of these pretty animals, squirrels, which sometimes do great damage in woodlands where they are allowed to increase largely in number.

The national apathy with regard to Forestry is shown by the fact that, even if large landowners had funds and desired to plant extensively, far from Government holding out any inducements to encourage them in this respect, the growing of timber is hampered with various restrictions that might easily be remedied by legislation. Yet the Houses of Parliament, the two great representative bodies of landowners in the United Kingdom, have never thought it worth while to compel Government, as they might do any time they liked, to relieve timber-growing of any of the disabilities under which this branch of rural economy labours, and which often make all the difference between a profit and a loss with so bulky and heavy a crop as timber.

Most of these disabilities have already been incidentally alluded to in the previous chapter (see p. 41). The present **Rating of Woodlands** must more or less interfere with planting. The rates are paid annually, and therefore increase at compound interest like all other investments of capital; yet long periods of time must elapse before the owner can obtain any return for the cost of planting, or the ground rent, or annual rates, or outlay for weeding, clearing, tending, and protecting, before even the early thinnings yield the slightest income. Considering how long woodland crops take to mature, and to how many dangers they are exposed from storms, insects, fungous diseases, &c., the owner of woodlands might easily be allowed some easement by not being called upon to pay the amount of the simple total of annual ratings (free from accumulation at compound interest) till the year in which the timber crops on any given area are mature or are being utilised.[1]

I have just planted over 100 acres at a cost of £6, 10s. an acre, plus the cost of fencing, and as, in order to keep out rabbits from adjoining land, I have had to wire it all round, I put the total cost at not less than £7, 10s. an acre. For twenty years certainly, and probably for thirty years, this land will produce no income whatever, and yet I shall have to pay rates and income-tax on an estimated value of about 5s. per acre during the whole of that time, whilst my son will have to pay a death-duty on a valuation of which he will not live to realise more than a very small part, if any.[2]

Damage from Sparks thrown out by railway locomotives, for which the railway companies are at present not legally responsible (though owners of traction-engines on roads are), makes the formation of Conifer plantations along the sides of railway lines rather a risky business, because serious damage may thus arise at any time during hot, dry seasons.

Perhaps a still greater injury is done to landowners, however, by the preferential "through charges" given to imported timber. This, together with the system of measurement used by the railway companies, handicaps home-grown timber heavily ; and all the loss in the local value of the timber must ultimately fall on the landowner, because the prices paid by wood merchants are based on the sum the timber will cost them when delivered in their mill-yard or other place of destination.

Monetary assistance is, however, the form of State encouragement most necessary to enable private landowners who may believe in the future upward tendency of the timber market to plant for their own profit and for the benefit of the country at large. Until the passing of the *Improvement of Land (Scotland) Act*, 1893, owners of land in Scotland were only able, with the sanction of the Board of Agriculture, to charge their estates for the planting of woods and trees in cases where the planting was for the express purpose of providing shelter. By that Act this limitation was removed, and applications may now be made to the Board for sanction to charge estates with the cost of planting, whether for shelter or otherwise. The *Settled Land Act*, 1882, provided similar assistance in England, and the *Improvement of Land Act*, 1899, consolidated and amended all previous Acts throughout Great Britain. Sums borrowed may now be repaid by a

[1] In Scots law, under the *Valuation of Lands Act*, 1854, s. 6, in estimating the yearly value of lands and heritages, the same shall be taken to be the rent at which, one year with another, they might in their actual state be reasonably expected to let from year to year. Where they consist of woods, copse, or underwood, the yearly value shall be taken to be the rent at which they might in their natural state be reasonably expected to let from year to year as pasture or grazing lands (Bell's *Dictionary and Digest of the Law of Scotland*, 1890, p. 1106).

[2] Elwes, in *Trans. Surveyors' Institution*, vol. xxxvi., Part VII., 1904, p. 218.

rent-charge extending to a period not exceeding forty years; but as even quick-growing Conifer crops would often, under conservative treatment, take longer than this to become fully mature, the advantages of extending this period to fifty years or more seem worth considering.

The money expended on improvements and all expenses may be charged in one sum on the estate. The loans under the Company's special Act are repayable by instalments during any period not exceeding twenty-five years; and the rent-charge, to repay capital and interest within that period, is at present £5, 19s. 1d. per cent per annum, payable half-yearly, for advances of £300 and upwards, and £6, 14s. for advances under £300. Under the Improvement of Lands Act, 1899, the Board of Agriculture may extend the period of charge to forty years, in which case the annual rent-charge for sums of £300 and upwards is at present £4, 11s. 6d. per cent per annum, payable half-yearly, and £5, 8s. 3d. for advances under £300 (Prospectus of *Scottish Drainage and Improvement Company*, p. 11).

Important differences exist in regard to timber on entailed estates in England and in Scotland. **Under English law** the timber is in general regarded as part of the estate in trust. Money arising from its sale is treated as capital, and only the interest on its investment is paid to the owner-in-possession. The word **timber** includes, as a rule, only Oak, Ash, and Elm; but it extends to other trees by local custom comprised in this term.[1] **Under Scots law**, however, the owner-in-possession has an uncontrolled right to fell and dispose of timber, the main features of the law as to woodlands on Scots estates-in-tailzie being as follows (Bell's *Dictionary and Digest of the Law of Scotland*, 1890, pp. 1078, 663, 1059):—

Growing Timber.—Questions regarding the right to use growing timber may occur between the fiar and the life-renter, the landlord and the tenant, and between the heir in possession under an entail and the next substitute.

"With regard to the rights of a life-renter, it was decided—see *Macalister's Transactions*, 27th June 1851—(1) that though a life-renter is entitled to ordinary windfalls of wood, he is not entitled to cut for sale any growing timber, or to sell trees blown down by an extraordinary storm; but he is entitled, at the sight of the fiar, to cut grown timber, or use blown-down trees, for repairing the fences and other purposes of the estate; (2) that he is not entitled at his own discretion to thin plantations, but he is entitled to do so at the sight of the fiar, to whom the cuttings belong; (3) that he is entitled to cut down copse-wood, which was in use to be cut down at intervals of twenty-two years, provided he is in possession when the usual period of cutting arrives; but he is not entitled to anticipate that period. . . .

"Life-renters are entitled to the fruits and annual produce of the subject life-rented; and they may possess by themselves, their servants or tenants; but

[1] An important case as to the right of limited owners of landed estates to cut timber and retain the proceeds was decided in 1891. From 1862 onwards Lady Dashwood was tenant-in-life of large estates, mostly in Buckinghamshire. A great portion of them was under Beech-woods, and it was customary for the owner to cut down mature trees annually, and dispose of the wood to chairmakers. By the custom of the county, Beech trees are *timber;* and after Lady Dashwood's death the next heir contended that, in appropriating the proceeds of the sales, she had been taking what legally belonged to him and his successors. In granting the decision the court held, having regard to the actual practice on the estate rather than to the strict rule of law, that Lady Dashwood, in following the custom of her predecessors, had acted within her right.

the trees planted for ornament cannot be cut down by the fiar during the currency of the life-rent. The life-renter must leave the subject in as good condition as that in which it was at the commencement of the life-rent. In general, he has no right to cut growing timber, even though planted by himself. But there are exceptions to this rule in the case of (1) **underwood**, and ordinary (but not extraordinary) windfalls ; (2) **timber** required for the maintenance of the estate ; (3) **sylva cædua, or coppice-wood,** which is cut periodically, when it comes to maturity.

"Fiar, as contrasted with life-renter, is the person in whom the property of an estate is vested, burdened with the right of life-rent. . . . He cannot cut the ornamental timber, though he may make the necessary thinnings, not hurting the amenity.

"*Sylva cædua* is a wood which, on being cut, stoles out again for another cutting, so as, by proper management, to yield a yearly profit, which may be turned to account by a temporary usufructuary, as a life-renter or wadsetter on a good title, but not by a mere tenant, unless his lease expressly so provide.

"Woods are reserved to the landlord *ex lege*. And even a lease of lands with 'woods' gives only the power of cutting wood for repairing or building houses upon the ground, but not of selling or otherwise disposing of the wood. The tenant in such a case may cut willows, when young, as a crop, but he is not entitled to cut willow-trees of a large size. A tenant selling or destroying the timber on his farm renders himself liable to a claim of damages, or to certain statutory forfeitures.

"An heir in possession under an entail is entitled to cut the timber as long as his possession lasts. In one case in which an heiress of entail, who was eighty years of age, quarrelled with the next heir, and advertised a sale of all the planted timber on the estate, the court refused to grant an interdict, although the heir offered the value of the whole if preserved. The court have, in a few instances, granted interdict against the sale of unripe timber, or ornamental timber, necessary to the amenity of the mansion-house ; but it has been remarked that it requires a strong case to authorise judicial interference. There has been some fluctuation in the decisions on the question, whether the heir in possession can give a right to cut timber, to last beyond his own life ; but it would appear that he cannot."

Concerning Technical Education in Forestry.—As already mentioned (pp. 35 and 42), certain preliminary steps have been taken during the last eleven or twelve years to provide facilities for technical education in Forestry, and hopes seem justified that greater progress will be made in the immediate future. But very much still remains to be done before a knowledge of Sylviculture can be said to be easily obtainable in Britain. One of the great difficulties found by a landowner desirous of working his woods mainly on business principles is to find a well-trained forester. And at the same time there are very few landowners or agents who have had any opportunities of making themselves well acquainted with both the principles and the practice of Forestry ; for the mere theory is useless without the practical knowledge, and rule-of-thumb practice often leads to great mistakes unless guided by acquaintance with technical principles.

Forestry, like Agriculture, must adapt itself to the peculiar conditions and requirements of the country, and even of the particular part of the country, in which it is to be practised. A forester, trained in Continental methods of Sylviculture, could not apply, as a matter of course, the same practical methods to English, Scottish, or Irish woodlands that may have been found to give the best practical results in different parts of France or Germany. Nevertheless, the fundamental principles underlying the art of Forestry are on the whole the same everywhere, though great differences may exist as regards the practical application of those principles in the management of woodlands under varying climatic and physical conditions.

In all our colonies and dependencies in the tropical, subtropical, and temperate zones there is much that is peculiar to their respective climates, and which has to be considered before the forester can deal properly with their woodlands. But the scientific principles remain the same, no matter how greatly the concrete factors of soil, situation, climate, and species of trees may vary. Foresters should therefore have a fair knowledge of the cognate sciences bearing on the art of Forestry, otherwise they may come to wrong conclusions when dealing with different classes of woodlands than those they have previously been acquainted with.

With regard to these *Cognate Sciences*, it is not in the least necessary that the forester should be a botanist, a geologist, an entomologist, a chemist, or a mathematician,—indeed, it is of far greater importance that he should be a practical man with a fair share of common-sense,—but he cannot acquire a proper knowledge of the art of Forestry without having at least a fair *elementary* knowledge of botany, geology, zoology, agricultural chemistry, and arithmetic. *Vegetable Physiology and Agricultural Chemistry* are the main scientific bases upon which the art of Forestry rests, and *Arithmetic and Book-keeping* are what are most needed in recording and understanding properly the results attained in practice by the application of the theoretical principles; but a fair knowledge of the morphology, anatomy, and classification of plants and animals is also necessary in order to acquire a trustworthy acquaintance with the nutrition of plants, the physiology of trees and woodland operations, the appearance and life-history of noxious and useful insects, the spread of fungous diseases, the physical properties of soil and situation, &c.

There are three distinct classes for whom good, thorough, technical instruction in Forestry is required—1. Practical Foresters; 2. Land-agents; 3. Landowners.

1. **The Practical Forester or Wood Bailiff** should possess a good ordinary board-school education of the higher standard in rural districts. Upon such a basis it is easy to graft all the technical knowledge required by the practical forester in the direction above indicated. He should be taught the elements of botany, geology, zoology, and chemistry, special attention being given to vegetable physiology, and to what, for want of a better term, we call agricultural chemistry; the appearance and life-history of the plants (including fungi) and animals (especially insects, game, and wild birds) he may have to deal with; the diseases of trees, and the injuries caused by insects and fungi; the measurement of felled and standing trees, and of the quantity and rate of growth of standing crops of timber; of simple valuation, and the use of tables of compound interest; of sowing, planting, thinning,

and felling; of the protection of woodlands, and the utilisation of woodland produce; of elementary land-surveying, plan-drawing, drainage, and simple construction; and of book-keeping and making out accounts.

But in addition to this elementary, comprehensive, theoretical instruction, a thorough practical course in the woods is an absolute necessity. This practical work in woods was unfortunately impossible in connection with the excellent *Course of Free Instruction for Practical Foresters and Gardeners* begun in 1892 at the Royal Botanic Garden, Edinburgh, for there are no woodlands where the theoretical teaching can go hand in hand with practical work.[1] The course inaugurated at the Forest of Dean in January 1904 is the only one at present in the United Kingdom where the proper combination of practice and theory has yet been effected, though it is probable that Scotland, Ireland, and Wales will also soon be provided with somewhat similar facilities for technical instruction. At Coleford, in the Forest of Dean, the course will extend to two years, and will include Forest Botany, Sylviculture, Forest Mensuration, and Protection of Woods. Six young men, already employed in the Dean Woods, and two from Windsor, are at present all that could be admitted to the advantages of this course; but it is hoped that next January the benefits may be extended to other eight men, who will be employed as woodmen while going through this training.[2]

[1] This course, for which a temporary grant of £150 a-year was obtained from the Board of Agriculture, was begun at the Royal Botanic Garden on 17th November 1892. The desire there even then was for technical instruction may be judged from the fact that the number of applications received from young gardeners and practical foresters for the benefit of the scheme was sixty-seven, of whom forty-four were admitted to the course. Some of these were taken on at a weekly wage as gardeners in the Arboretum, whilst the others received employment in the various nurseries around the city.

In inaugurating this course, due solely to his initiative, Prof. Bayley Balfour said that it was not intended to teach them in the class-room to be practical foresters or gardeners. That must be learnt elsewhere. But if they wanted to know the secrets of Forestry and of Horticulture, they ought to have a sound knowledge of the scientific basis upon which these arts rested. It was meant, therefore, to give them some insight into the sciences that underlay their work. During the winter they should have three courses—one on chemistry and one on physics; and, in addition to that, they should have a course on mensuration and land-measuring. This last course would be begun in winter, but more would be done at it when the long evenings came. They would then go out into the garden, where surveying instruments would be provided. They would be taught to use these instruments, to survey land, and to draw out plans. After these subjects had been gone through, they should then proceed to deal with botany, which treated of the actual plants they would handle; of geology, which treated of the soils in which the plants grew; they should also have a course of meteorology, giving them the application of physics to the study of climate; and a course on entomology, which would work into the course of botany, and would show them how insects affected forest and garden plants in health and disease. After that they should have lectures on Forestry and Horticulture, treated by experts from a practical point of view; and he hoped it would be possible to arrange for excursions to neighbouring estates and gardens.

[2] The Bavarian system, one of the best on the Continent, of training youths for the subordinate forest service of the State, is begun when they are from fourteen to sixteen years of age. It extends over two years, during which the lads go through a course of practical instruction, and receive tuition in the principles of Forestry, Arithmetic, Book-keeping, &c. There are five such elementary forest schools in different parts of the country.

2. and 3. **The Land-Agent and the Landowner** may be conveniently classed together with regard to the class of instruction they should receive. Of course, a large landowner who leaves the management of his estate to an agent no more requires a thorough acquaintance with Forestry than with Agriculture, although there can be no doubt it would be all the better for his tenants and himself if he were at home in both these branches of rural economy. As befitting men of higher education, the course for landowners and land-agents should go deeper into the theoretical bases of Sylviculture, and should consider the best systems of management and their results. In short, it should be far more of an academic character than the elementary instruction for foresters, though it should also be as practical as possible. The class-room instruction should be largely supplemented by excursions during all the different seasons of draining, planting, weeding and thinning, felling, &c.; and the practical work should include at any rate such manual operations as planting, so that an agent may show a raw hand the proper way to do the thing if he is not performing his work properly.

The usual curriculum provided on the Continent for head-foresters and landowners comprises (along with many other subjects—*e.g.*, higher mathematics, chemistry, surveying and road-making, forest law, hunting, fishery, &c.) the following four main branches of Forestry:[1]—

I. Sylviculture.—This is really synonymous with Forestry; but, as regards technical instruction, the term is limited to that branch of forest science which treats of the formation, treatment, and reproduction of woods. After preliminary instruction regarding the special characteristics of the timber-trees generally culti-

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[1] This instruction in the four main branches of Forestry is preceded by **Introductory Studies in the Cognate Sciences**, stating the aims and objects of Forestry from national-economic and proprietary points of view, and giving a concise account of the history of Forestry and the forest laws from the earliest times up to the present. To these introductory studies belong the general grounding in geology, botany, and zoology, the mathematical studies, and the application of mathematics to Forestry in surveying, levelling, and road-making.

(1) **Geology and Agricultural Chemistry (Pedology).**—Plants cannot grow without soil, and it is necessary to have a good knowledge of what is generally called "agricultural chemistry." This comprises geology, chemistry, meteorology, and treats of the mineral constituents of the various kinds of rocks; of their decomposition and the formation of soil; of the various physical properties of soils and subsoils; of the mutual relations between soil, subsoil, and vegetation; of the influence of latitude, elevation, gradient, and aspect on the growth of trees; of the influence of forests on temperature, atmospheric humidity, and soil-moisture; of the effects of different atmospheric conditions (wind, rain, snow, frost) on forest vegetation, &c.

(2) **Botany.**—The natural step from knowledge of soils is towards a knowledge of the vegetable covering they bear. The scientific forester on the Continent is taught not only the general principles of vegetable morphology, physiology, and pathology, but his special attention is directed to the plants most important to his work, and to the fungous and other diseases liable to damage or destroy them. Many useful hints being obtainable from the herbage and weeds covering the soil, he is taught to know most of these, whilst at the same time he is well grounded in everything relating to the forest trees of Europe and the chief exotic kinds that have been introduced for growth in the woodlands.

(3) **Zoology.**—Instruction is also given concerning useful and injurious birds and insects, and the habits of the game and vermin to be met with in the woods.

vated, their relations to soil and situation, the various modes of growing trees in highwoods, coppice, or coppice with standards, the advantages of mixed woods, this branch may be divided into three main sections—(1) the *Formation*, (2) the *Tending*, and (3) the *Reproduction or Regeneration of Woodland Crops.*

II. Protection of Woodlands.—This shows how—so far as lies in the power of the owner—woods can be protected against wind, fire, insects, &c., constantly threatening their healthy, normal growth. Some knowledge of the forest laws of the country is necessary in order to check or punish destructive acts like injury to boundary-marks, illicit appropriation of forest produce, or incendiarism. The importance of protecting forests from fire can only be known to those acquainted with tropical or subtropical countries, although even in the temperate zone—(*e.g.*, the Scots Pine woods on the great North-German plain)—costly and well-planned measures against fire are a necessity, and are not always successful. Apart from the actions of men, damage may also be caused by storms, snow, hail, frost, drought, insects, fungous diseases, &c., and the protection of woodlands teaches all that can be taught in the way of preventing, minimising, and repairing such damage. Dangers arising from inorganic causes like storms can, of course, never be totally obviated, though much can be done to minimise the risks and to repair damage as speedily and completely as possible.

III. Management of Woodlands and Valuation of Timber Crops.—This branch deals with the best and most methodical way of carrying out the landowner's wishes with regard to his woodlands, in respect of utilising to the best advantage the land and the capital in timber-crops. It is subdivided into four sections :—

1. **Organisation** of the executive staff, including arrangements of the forest areas into estates or divisions and subdivision into blocks and compartments for convenience of working. Directions regarding office business and cash and other accounts are needed in the case of very extensive owners, such as the State, when rules are generally laid down in code form for the guidance of those concerned.

2. **Timber Mensuration** includes not merely the measurement of logs, stacked timber, &c., but also the computation of the cubic contents of growing trees and whole crops of timber by means of sample areas, or by the use of average-tables, based on past results, arranged for the different kinds of timber, at different periods of their growth, and on the various qualities of soil and situation. It further teaches the best way of ascertaining the annual or periodical increase of growth in height, girth, and cubic contents, either for trees individually or for whole woods or portions of woods.

3. **Valuation of Woodlands** teaches the application of actuarial methods to the practical problems of Forestry.[1]

4. **The Formation of Working Plans.**—This teaches how to arrange work in a forest, with regard to areas and to periods of time, so as best to effect the end desired. The data requisite before any such arrangement of work can be made include a survey and plan of the whole area, a classification of the soils in different parts, a complete catalogue and description of the whole growing-stock of timber, an estimate of the rate of growth of each crop, detailed information relative to the mutual relation between growing-stock and annual increment, and a statement of the past income and expenditure. These data having been carefully considered, the "working plan" can be framed for twenty or thirty years, or

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[1] At German forest colleges and universities this part of the basis of forest management is, under the names of *Valuation and Forest Statics*, treated in quite an unnecessarily abstruse manner. For practical purposes, all that is really necessary is to teach the simplest method of actuarial calculations, with the use of compound interest tables.

whatever other period is desired ; and this, revised and amended every ten years, forms the basis upon which operations are conducted. It usually consists of—

(*a*) **An Introductory Report,** exhibiting the results ascertained from the data collected.

(*b*) **The Felling Plan,** forecast with a view to procuring equal falls of timber yearly or periodically,—and, so far as possible, of nearly equal annual value, and from nearly equal areas.

(*c*) **The Plan of Cultivation,** dealing with the regeneration of the timber-crops cleared, or the sowing or planting of fresh areas.

IV. Utilisation of Woodland Produce.—Those who are engaged in growing timber should be acquainted with its technical properties, for these are affected to a great extent by the treatment accorded to growing timber. By way of example it may be mentioned that, after years of hot and acrimonious dispute, it is now in Germany generally admitted that timber raised by natural regeneration is in many technical respects superior to that grown artificially in plantations ; for in the latter case the poles early begin to show a tendency to forked growth that is not usual in natural woods.

To be able to arrange timber in the most advantageous lots, the forester must know the uses to which various sizes and qualities are put. Shipbuilders, miners, railway contractors, furniture manufacturers, &c., all make different demands for timber ; and all can best be satisfied when their requirements are properly known and studied.

Forest technology also includes the preservation of wood by impregnation and other methods, making wood-pulp and cellulose, charcoal-burning, preparing peat, the collection, preparation, and transport of tree-seeds, &c. Last, and not least, instruction is necessary about the construction and working of saw-mills, for the forester is often called upon to work saw-mills, either by water-power or steam, in order to enable the produce to be disposed of to the best advantage, either by converting to suit local needs or by milling to standard sizes of planks and cuttings, and thus reducing to a minimum the cost of transport to the nearest profitable market.

Such are the special subjects forming the curriculum at the great forest schools on the Continent. In the Bavarian Forest Service only those who can produce their "leaving certificate" from the highest class of schools, which entitles them to matriculate at any university, can enter the Forest Academy at Aschaffenburg. Here they have a two years' course of preliminary instruction, followed by a two years' course of study at Munich University, and by three years of practical work, of which the first and third are in the State forests, and the second in the Forest Secretariat learning official routine. In Prussia the similarly qualified students have first of all one year's practical work as apprentices under an *Oberförster*, and then proceed for two-and-a-half years to either of the two Forest Academies (Neustadt-Eberswalde and Münden). After two years' practical work in the State forests, they have to attend a university for one year, and are thereafter employed on practical work (mostly in revising working plans) till they receive their appointments as *Oberförster.*

The course of theoretical instruction necessary for the practical purposes of Forestry in any part of the United Kingdom need be nothing like so elaborate, and need not occupy anything like so long a time, as the above-described course of technical training given in the great forest schools throughout Germany, France, and Austria. If one examines the Continental curricula, it will be found that the great bulk of the time during the two to four years' term of collegiate study (for officers) is taken up with the cognate sciences,—botany, zoology, geology, mineralogy, chemistry, physics, surveying and road-making, plan-drawing, higher mathematics. All of these have certainly a direct connection with Forestry, but any deep academic knowledge of them is not really necessary either for the general management or administration of woodlands, or for the practical operations of planting, managing, clearing, and regenerating woodland crops. Further, there are usually special courses of lectures on the history of forestry, on forest law, hunting, fishery, &c.; while the four main branches of Forestry—(1) *Sylviculture*, (2) *Protection of Woodlands*, (3) *Management of Woodlands*, and (4) *Utilisation of Woodland Produce*—are not only taught in distinctly separate courses of lectures, but integral portions of these branches are even elevated into self-contained series of lectures on forest botany, forest entomology, lectures on soil and situation, mensuration of timber crops, forest finance, forest technology, forest policy, &c. Much of what is taught (especially in Germany) is purely academic, and has really no practical value for work in the woods. Given a sufficiently well-correlated knowledge of vegetable physiology and agricultural chemistry—the two great bases upon which the art of Forestry (like that of Agriculture) must establish itself—all the indoor instruction that it is necessary to give with regard to these four main branches of Forestry should be conveyed by a capable teacher in a comprehensive course of 100 to 120 lectures, given during the summer months, and illustrated by outdoor demonstrations in the shape of weekly or fortnightly visits to instructive woodland centres. Such a course could easily be arranged at any university or agricultural college during the summer session of each year, when 100 to 120 lectures of one hour each could be given at the rate of 2 per diem on fifty to sixty days, and supplemented by from 5 or 6 to 10 or 12 illustrative excursions to wooded centres on Saturdays. And, if considered desirable, this short course of instruction might be further improved by an excursion for about a fortnight to the Continent, to see Forestry carried on both on a much more *extensive* scale and in a far more *intensive* manner than obtains in any part of the United Kingdom. But, of course, the ability of the teacher to impart his knowledge and to interest the students in the subjects taught will have far more to do with successful instruction than the mere number of the lectures assigned to the course in a syllabus.

I venture again, without any hesitation whatever, to repeat the assertion that a good theoretical, and, as far as possible, at the same time practical, grounding in the four main branches of the art of Forestry, as applicable to Great Britain and Ireland, is quite capable of being conveyed in a course of 100 to 120 lectures of one hour each, supplemented by 5 or 6 excursions to woodland centres on alternate Saturdays, or, preferably, 10 to 12 weekly excursions, if practicable. I make it an essential proviso, however, that such a course of lectures be given only between April and October (and preferably May to July), when the woodlands are in full energy of growth, when birds, insects, fungi, &c., can best be studied, and when the best and largest number of object-lessons can be seen during the longest days of the year. These lectures should be distributed over the four main branches of Forestry in something like the following proportion :—

		Lectures.
I.	Introduction (and British *Sylva*) . . .	10 10
II.	Sylviculture	30 or 40
III.	Protection of Woodlands	20 or 25
IV.	Management of Woodlands	20 or 25
V.	Utilisation of Woodland Produce . . .	20 20
	Total	100 or 120[1]

To bring such instruction within easy reach of the rising generation of prospective landowners, it would have to be arranged for at both Oxford and Cambridge Universities; whereas for land-agents it might most suitably form part of the course of instruction given at Edinburgh University, the Royal College of Science in Dublin, and at Agricultural Colleges in England, following the example set by Cirencester in 1903 and Wye in 1904.

[1] The course of instruction now being given (during the winter months) at Edinburgh University consists of—

		Lectures.
1.	Introductory	4
2.	Sylviculture	39
3.	Protection	20
4.	Management	7
5.	Utilisation	18
	Total	88

The lectures are supplemented by 9 excursions to woods, nurseries, and timber-yards, &c. (See Bailey in *Trans. Roy. Scot. Arbor. Socy.*, vol. xvii., part ii., 1904, p. 206.) But winter is not the best time for visiting woodlands and nurseries in search of object-lessons.

CHAPTER III.

THE CLIMATIC AND PHYSICAL INFLUENCE AND THE NATIONAL-ECONOMIC IMPORTANCE OF WOODLANDS.

The existence of large masses of woodland in any country is productive of a twofold influence—climatic and national-economic.

The general climatic and physical effects are :—

1. To equalise the atmospheric and the soil temperature, and to diminish extreme differences in each of these.
2. To increase the relative humidity of the air, and perhaps also to some slight extent the aqueous precipitations (dew, mist, rain).
3. To absorb and retain moisture in the soil, thus tending to obviate freshets and floods, and to provide for the perennial flow of springs and streams, and to act as a filter in purifying the water-supply in catchment areas.
4. To protect the surface-soil from erosion during rainfall.
5. To assist in purifying the atmosphere from excess of carbonic acid, &c.

The special national-economic advantages, which, of course, vary greatly according to the given conditions of each country, are :—

1. To provide sources of employment for part of the rural population in planting, tending, and felling timber-crops ; in collecting, preparing, and handling timber and other woodland produce.
2. To increase trade and industry generally, in transport by land and water, sawing, &c., and preparing the raw material for tradesmen.
3. To provide home-grown supplies of timber, so that the country may be either independent of, or at any rate less dependent on, supplies of foreign timber for its internal requirements.
4. To benefit agriculture and stock-growing by providing shelter from wind and excessive drought.
5. To increase facilities for sport, and thus add to the attractions of country life.

I. The General Climatic and Physical Influence of Woodlands.— Even in early Roman times it was known that excessive clearance of woodlands soon brought about undesirable changes in the physical conditions of Italy, and affected the welfare of the rural population. And a similar experience has been felt wherever large masses of woods have been destroyed, the effects being, of course, most evident in localities with a warm, dry climate. Thus, in 1803, the Agricultural Society of Marseilles reported that in consequence of the reckless destruction of the woods after the Revolution of 1789—

> The winters are colder, the summers hotter and drier, and the beneficial spring and autumn rains no longer fall regularly; the Uveaune river, flowing from east to west, rushes down in flood with the least rain, carrying away its banks and flooding the richest meadows, while for nine months of the year its bed lies dry owing to the drying up of the streams.

Though the great Indian famines, which recur from time to time in consequence of the S.W. monsoon rains proving insufficient in quantity, cannot be mainly due to any such cause, yet it is beyond any doubt that the stimulus given to the rapid clearance of woodlands throughout the dry portions of India under British rule has greatly intensified the amount of damage caused by drought. The famines in S.E. Russia are said to be mainly due to the destruction of the vast forests that has been going on for over thirty years past.

> It is said that this gigantic natural tillage farm [the "black-soil" region] was formerly hedged in by belts of forest, which served the twofold purpose of sheltering it from the desert winds and of increasing the humidity of the climate. It is certain that these forests do not now exist, and that the black-soil country is often scourged by devastating blasts from the steppe, and not infrequently baked by prolonged droughts. The desert winds pile the snow into drifts in winter, which become the source of destructive torrents in the spring. In summer the same winds are so fierce and arid that in the space of a few hours they wither the corn as it stands, while, when they are laden with sand, they smite the soil itself with perpetual barrenness. (*Report on Agriculture in the S.E. Provinces of European Russia*, by Major Law, commercial attaché, St Petersburg, 1892.)

The oldest meteorological observations regarding woodlands were begun by Pictet and Maurice near Geneva in 1796-1800, and these were followed by others made by Kaemtz in Germany during 1831-34. In 1858 Becquerel made observations regarding the effect of woods on temperature and rainfall, and in 1859-60 the French Government tried to determine the quantity and distribution of the rainfall in the woods at selected stations. In 1860 Nördlinger and Krutzsch, in Germany, made observations similar to Becquerel's at nine different forest centres. In 1867 Professor Ebermayer of Munich introduced the system of parallel observations at seven stations within the woods and in the open, on otherwise similarly situated spots, and the publication of the results of his observations (*The Physical Influence of Woodlands on Atmosphere and Soil*, 1873) resulted in a more extensive application of his methods of observation. Other seventeen of such stations were opened in Germany, and others in Switzerland, Austria, and Italy. After maintaining records for twenty-two years, these affiliated stations have completed their work, and the following main results attained may be accepted as conclusive:[1]—

1. **As regards Atmospheric Temperature.**—*The annual average temperature* within woodlands growing in closed canopy is generally somewhat lower than in the open, but this difference is usually only about ½° Cent., and seldom exceeds 1° Cent. on an average of several years. Of more importance, however, is *the difference in temperature at the various seasons of the year*, because here the influence of the woodlands becomes more apparent. The difference is greatest in summer, is very small in winter, and is about midway between these extremes in spring and autumn—that is to say, the chief effect of woodlands is to mitigate extreme heat in summer, when the difference in temperature between the woodlands and the open is more or less proportional to the increase in the atmospheric temperature. This is shown by the following summary of the observations taken in different countries:—

The mean temperature in woodlands was cooler (−) than that in the open at 5 ft. above ground, by Cent.°				
Based on all the observations made in	Spring (March, April, May).	Summer (June, July, August).	Autumn (Sept., Oct., Nov.)	Winter (Dec., Jan., Feb.)
Prussia . . .	−0·23	−0·76	−0·35	−0·05
Bavaria . . .	−1·27	−2·04	−0·74	−0·47
Switzerland . . .	−0·74	−1·51	−0·87	−0·51
France . . .	−0·43	−1·03	−0·70	−0·37
Würtemberg . .	−0·80	−1·70	−0·50	−0·30
Mean . .	−0·69	−1·41	−0·63	−0·34
The mean temperature in crowns of trees was cooler (−) than that in the open, by Cent.°				
Prussia . . .	−0·06	−0·40	−0·22	−0·08
Bavaria . . .	−0·42	−1·07	−0·27	−0·00
Würtemberg . .	−0·50	−1·00	−0·20	−0·00
Mean . .	−0·33	−0·82	−0·23	−0·02
The mean temperature in woodlands was cooler (−) than that in the open at 10 feet above ground, by Cent.°				
Switzerland—average of twelve years	−0·74	−1·51	−0·86	−0·51

[1] For the above and the following details I am mainly indebted to Weber's *Die Aufgaben der Forstwirthschaft*, in Lorey's *Handbuch der Forstwissenschaft*, 2nd edit., 1903, vol. i. pp. 27-61.

The prevention of insolation of the soil during the long hot days of summer, and the rapid transpiration taking place through the foliage, exert a greater influence on the atmospheric temperature than can be ascribed to shelter from wind and to decrease of nocturnal radiation. Consequently, when large tracts of woodland are cleared, the chief effect is to cause an increase in summer warmth.

In the crown of the trees, where insolation by day and radiation by night make their full influence felt, the difference in the daily average over the whole year is less than it is near the ground. In winter it usually averages little either above or below 0°, and in summer usually about the half of the reading at 5 ft. above the ground.

As regards daily variations in temperature, in woodlands the air is cooler during the day and warmer during the night than in the open, as is shown by the following table :—

The mean temperature at different times of the day in the woodlands was cooler (−) or warmer (+) than that in the open, by Cent.° (on average of fourteen sets of recording stations, and for the five years 1886-1890).

Time of observation.	Spring.	Summer.	Autumn.	Winter.
Mean night minimum .	+0·64	+1·01	+0·80	+0·59
8 A.M.	−0·56	−1·40	−0·44	+0·09
2 P.M.	−0·84	−1·80	−1·04	−0·39
Mean day maximum .	−1·37	−2·67	−1·55	−0·71

During the night the trees interfere with the radiation of heat, and in the daytime the shade afforded by the crowns keeps the air from being rapidly warmed by the sun's rays. These influences are naturally strongest during summer, when foliage is most abundant, and least in winter. In winter, too, coniferous forests with evergreen foliage are warmer than deciduous forests.

Owing to these differences in temperature, beneficial currents of air are induced between the forests and the open country, which follow the same law as obtains in regard to land and sea breezes. During the day the cooler and moister air of the forest sets outwards to take the place of the heated air ascending in the open; while at night the current sets in from the open, cooled by radiation, towards the forest.

While the above statistics prove that the main climatic influence of woodlands is to modify the daily maxima and minima of atmospheric temperature, a comparison of the absolute extremes of atmospheric temperature during the year exhibits definitely the sum-total of the influence exerted thereon by woodlands.

The observations made at ten stations in Prussia during twenty-one years (1875 to 1895) showed that the woodland air was cooler (−) in summer and warmer (+) in winter by the following amounts in Cent. ° :—

Height of observation.	Average difference during highest temperature in July.	Average difference during lowest temperature in January.
At 5 ft. above ground .	−3·36 (greatest −6·50)	+1·56 (greatest +5·30)
In the tree-crowns .	−2·54 (" −5·40)	+3·55 (" +4·00)
And the observations made at the Bavarian stations showed the following differences :—		
At breast-height ($4\frac{1}{3}$ ft.)	−4·23 (greatest −5·30)	+0·78 (greatest +2·10)

This modification of the extremes of temperature (and especially of the summer maximum by $3\frac{1}{3}°$ to $4\frac{1}{2}°$ Cent.), which are bad alike for man and beast, and are also unfavourable to agricultural operations, is the chief climatic influence of woodlands. It is usually of immense importance from a national-economic point of view, since many places that were once fertile are now little better than barren wastes in consequence of the reckless denudation of forest (*e.g.*, the Karst in Austria, and the Russian steppes).

Owing to their dense foliage and complete canopy, Beech forests exert a considerably greater influence in diminishing the extremes of summer temperature than forests of Spruce or Scots Pine ; but after the fall of the leaf in autumn their influence is very similar to that of the Pine forest, and only half so great as that of the more densely foliaged Spruce.

2. **As regards Soil-Temperature.**—The influence exerted on the soil-temperature by woods growing in close canopy is of great importance with regard to the soil-moisture. Observations have shown that the mean annual temperature of the soil in woodlands is at all depths of observation (extending to 4 ft.) cooler than in the open, and that the differences are greatest in summer and least in winter. In countries with very warm summers this

The mean annual temperature of woodland soil was cooler (−) than that in the open, by Cent.°					
Based on all the observations made in	Surface-soil.	At 1 ft. deep.	At 2 ft. deep.	At 3 ft. deep.	At 4 ft. deep.
Prussia (mean of nine to fifteen years)	−1·42	−0·90	−1·05	−1·04	−1·07
Bavaria . . .	−1·99	−1·82	−1·96	−1·90	−1·90
Würtemberg . .	−1·50	−1·40	−1·80	−1·70	−1·60
Mean average .	−1·64	−1·37	−1·60	−1·55	—1·52

reduction of the soil-temperature over large areas by means of woodlands has a very beneficial result. According to observations made in Würtemberg, the difference between the maxima of soil-temperature in woodlands and in the open can extend up to 14° Fahr.

The daily differences in soil-temperature are found to vary according to the season of the year; but throughout nearly the whole year the upper layers of soil in the open are warmer in the afternoon than in the forenoon, whereas in the woods the variations are inconsiderable.

As with regard to the atmospheric temperature, so also here the influence of woodlands in equalising the soil-temperature throughout the year is greatest in the case of trees whose foliage is densest, the evergreen Spruce heading the list.

The influences above considered are all increased through the variation in temperature of the air circulating throughout woodlands themselves. An air current touching the surface of the soil and then ascending for 60 to 90 ft. into the crowns of the trees comes into contact with the stem, branches, and leaves; and the greater the difference between the temperature of these and of the air itself, the more will the temperature of the latter be affected by such contact. Observations have therefore been made to determine the temperature of the trees, and it has been found that in summer they are always cooler than the surrounding air, while in winter they are sometimes slightly warmer. The mean of Swiss observations extending over twelve years (1869-1880) showed that the temperature of the trees was on the average cooler (–) than the air surrounding them by Cent.° :—

	Spring.			Summer.			Autumn.			Winter.		
	Larch.	Spruce.	Beech.	Larch.	Spruce.	Beech.	Larch.	Spruce.	Beech.	Larch.	Spruce.	Beech.
Mean of twelve years' observations at 10 ft. above ground	– 2·11	– 3·37	– 1·52	– 3·34	– 4·06	– 3·18	– 0·96	– 2·25	– 1·51	– 0·36	– 0·95	– 0·29

These observations also showed that in the daily range of temperature the trees are generally cooler than the surrounding air during the daytime, while at night they are usually only very slightly cooler, and frequently somewhat warmer, than the air. The lower parts of stems are nearer to the soil-temperature, and the upper parts nearer to the atmospheric temperature, mainly in consequence of the rise of sap.

3. **As regards the Degree of Atmospheric Humidity, and the results of the Aqueous Precipitations.**—The capacity of the atmosphere for absorbing aqueous vapour is largely dependent on its temperature. The higher the temperature of the air, the greater is its power of retaining moisture in the form of water-vapour; and for each degree of temperature there is a *point of saturation* beyond which any excess of moisture contained in the air cannot be absorbed, but must take the form of fluid either in the shape of rain or mist. This point of saturation is well known (having been fixed by experiments) for each degree of temperature. But as the capacity of air for absorbing and retaining aqueous vapour increases with any rise of temperature, and diminishes with any fall, one must consequently distinguish between

the absolute humidity of the air, or the quantity of aqueous vapour held in solution in gaseous form at any given time, and *its relative humidity*, or the percentage of aqueous vapour actually then held as compared with the possible maximum or *point of saturation* (= 100) for the given temperature. It is important that this essential difference between *absolute* and *relative* atmospheric humidity be kept in view, in order to understand the influence of woodlands on the moisture contained in the air.

Throughout all the countries in Western Europe, and in none more so than over the British Isles, the strength and direction of the vapour-laden atmospheric currents depend on the distribution of warmth and air-pressure over the Atlantic Ocean,—just as the chief rains throughout India depend on the force and temperature of the S.W. monsoon winds during the summer solstice. Fresh supplies of atmospheric moisture are, with more or less of regular periodicity, being wafted in from the great ocean by each westerly or south-westerly wind. Although more or less periodic, these variations in atmospheric conditions (or "changes in the weather") are throughout Western Europe much less apparently connected with the earth's position towards the sun than is so evidently the case in hotter tropical and sub-tropical countries. But variation and irregularities in climate, particularly with regard to atmospheric moisture, are caused by the configuration of the earth's surface (in the shape of mountains, valleys, and plains) and by the distribution of land and water; and it is in consequence of this that large compact masses of woodland exert great influence on the atmospheric humidity.

As the woodland air is from day to day during summer on the average about $1\frac{1}{2}°$ Cent. cooler than that of the open country (in the case of Beech it was found sometimes to exceed $4\frac{1}{2}°$ Cent.), and as at the same time the difference between the mean temperature of the soil and of stem, branches, and foliage of the trees on the one hand, and the mean atmospheric temperature on the other, usually increases with the degree of summer warmth, it therefore follows that a current of air passing through a wood must be reduced in temperature and brought nearer to the point of saturation. Or in other words, its *relative humidity* becomes increased, and this influence is enhanced by the large quantities of water transpired into the air through the foliage during the period of active vegetation from spring till autumn (and even in winter by evergreen Conifers). But if the air was already at the point of saturation, any such reduction of temperature would compel it to part with some of its water-vapour in the form of aqueous precipitation (dew, mist, rain). This higher relative humidity of woodlands, as compared with the open, is always shown by hygrometric measurements, and it is often so marked as to be quite apparent to the human senses. The results of five years' observations (1886-1890) at the Prussian stations, and of twelve years' observations at Swiss stations, showed that at 5 ft. above the ground the woodland air had a higher (+) mean relative humidity than the air in the open by the following percentages :—

Season.	Prussia.			Switzerland.		
	Beech.	Spruce.	Scots Pine.	Beech.	Spruce.	Larch.
Spring . . .	+1·0	+3·4	+3·8	+2·3	+9·6	+2·8
Summer . . .	+7·9	+5·4	+7·6	+8·5	+11·1	+7·8
Autumn . . .	+4·6	+4·8	+5·1	+4·2	+10·8	+5·5
Winter . . .	+1·9	+1·4	+2·2	−0·7	+8·4	+0·3
Mean annual difference (percentage)	+3·8	+3·7	+4·7	+3·6	+10·0	+4·1

But with respect to the *absolute humidity* of the air, the total results of all the observations made fail to prove that the woodland air shows any constant or marked difference from the air in the open.

After correction, in order to eliminate, so far as possible, local differences due to altitude and to other physical dissimilarities of the meteorological stations, the results of the recorded observations show that the mean annual relative humidity of woodland air is, on the average, from at least 3 to at most 10 per cent greater than that of air in the open; while the difference varies according to the season of the year, being greatest in summer and autumn, and least in winter and spring. They show, too, that large areas covered with Spruce will, on the average, be from 3 to 9 per cent moister in spring, as well as cooler, than those under woods less densely foliaged. In Bavaria it was found that in summer, in consequence of the density of the foliage in Beech-woods during the most active period of vegetation, the average difference was from 8 to 13 per cent greater than the relative humidity in the open. But, as above remarked, if this air was already in the open at or near the point of saturation, then the effect of the cooling process, on its being wafted into the woodlands, is that a certain amount of surplus moisture, beyond the aqueous vapour that can be held by the air up to the point of saturation at its reduced temperature, must be released and precipitated in aqueous form (dew). Woodlands therefore act as condensers of atmospheric moisture, and decrease the absolute humidity of the air whilst increasing its relative humidity. This is of importance with regard to dewfall; and wherever the soil can radiate its heat during the night (as on fields and pastures bordering on woodlands), the amount of dew deposited is greater than in the open country.

Endeavours have been made to establish, by means of careful observations, the effect of forests in regard to the precipitation of aqueous vapour in the form of dew, mist, or rain, but the results are often of so conflicting a nature that, up to the present, deductions can no more safely be drawn now than was the case ten years ago. In order to compare observations made in the forests with those made at the usual meteorological stations in the open, a correction would in each case be necessary to reduce the localities to the same sea-level, as air cools in rising and increases in relative humidity—*i.e.*, it approaches the point at which it must precipitate some of the aqueous vapour held by it.

Hence mists and rainfall generally increase with the height of a locality above the sea-level, although no directly proportional increase can be proved. They vary with the geographical position and the physical conditions of each point of observation, whilst variations in the direction of the moist winds at any one locality may prevent reliable comparison with readings made in other localities.

The mean statistics of readings made for twenty-two years (1876-97) at many points of observation in Germany, as well as many observations made in other countries, corrected as carefully as is possible with reference to the above-mentioned causes of difference, seem capable of yielding no other general inference than that at high altitudes large extents of woodland probably increase the local rainfall considerably. *As regards the quantity of rainfall and snowfall which is intercepted in woodlands* by the leaves, branches, and stems of the trees, the observations made in Switzerland, Prussia, and Bavaria prove that about one-fourth of all the aqueous precipitations is intercepted by the trees, and is mostly given off again by evaporation, though small quantities are gradually conducted down the stems to the soil. In lofty forest-clad regions the erosive action of heavy rainfall on the surface-soil is thus very much modified. The Prussian observations showed, as the mean of ten years, the following average results :—

Class of woods.	Percentage of total rain and snow.	
	Reaching the soil.	Evaporated from the trees.
Beech . . .	76	24
Spruce . . .	78	22
Scots Pine . .	73	27

By means of their lower temperature, their greater relative humidity, and the mechanical obstruction they offer to the movements of currents of air, extensive woodlands certainly act as condensers of the aqueous vapour contained in the atmosphere, and their influence in this respect is more marked at high altitudes and in mountainous districts than on plains or near the sea coast, where other physical factors come into competition with and modify it. More convincing proofs than have yet been obtained are still, however, necessary before the assertion can be made that in all cases extensive woodlands directly cause any increase in aqueous precipitations, irrespective of local conditions as to the ruling direction of winds and the configuration of the land. The observations made up till now, however, seem to indicate that in the vicinity of extensive woodlands the rainfall is greater than at localities further off, but under otherwise similar physical conditions.

In portions of the Russian steppes, planted between 1843-1890, the inhabitants assert that the summer rainfall has considerably increased, that the danger to crops from drought is not so great as formerly, and that the wheat crops are therefore, on the average, heavier now than before, whilst the villages are also protected by the forest from the violence of the winter storms.

In order to ascertain the effect of these plantations (extending to about 5000 acres), observations were made from 1893 to 1897, with the result that the mean annual aqueous precipitations (rain and snow) were found to amount to 22·51 in. in the woodlands and to 18·13 in. in the open steppe, the former showing an increase of 23·9 per cent over the latter. The influence of the woodlands was plainly seen even in the dry season, and in the summer of 1895 the rainfall in the woods (9·87 in.) was 16·4 per cent greater than that in the open (8·48 in.)

4. **As regards Evaporation of Soil-Moisture.**—The low temperature and the high relative humidity of the woodland atmosphere are both unfavourable to rapid evaporation; but a still greater hindrance to it is the protection afforded to the soil against direct insolation and the action of winds. From observations extending over ten years (1876-85) in various parts of Germany and Austria, the following relation is shown between evaporation in woodlands and in the open in the vicinity of the forests; while the differences would probably be greater if comparisons had been made with places in the open that were far removed from the modifying influence of the woodlands:—

	Water evaporated.	
	Inches.	
In the open	20·9	The practical importance of this will be seen, when it is recollected that the mineral food in the soil can be taken up by the rootlets of trees only in the form of *soluble* salts.
In the woods	9·5	
Lower in woodlands than in open by .	11·4	
	Per cent.	
Evaporation in woodlands expressed in percentage of that in the open	46	

The Prussian observations for the ten years 1876-1885 showed the following mean results:—

Class of woodland.	Soil-moisture evaporated in the open=100.	
	Percentage of soil-moisture evaporated in woodlands.	Percentage of moisture retained in soil.
Beech	40·4	59·6
Spruce	45·3	54·7
Scots Pine	41·8	58·2
Young plantations . .	90·3	9·7

The action of forests is, therefore, to retain in the soil a large proportion of the rainfall or of the moisture arising from the melting of snows; and this retained moisture, by percolation to the lower layers and the subsoil, tends to feed the streams perennially, and to maintain a constant supply of soil-moisture, without which trees could not derive their requisite food-supplies from the soil.

The nature of the soil-covering below the trees also exerts considerable influence on the amount of moisture evaporated. From experiments conducted during five years in Bavaria it was found[1] that a good layer of fallen leaves, and of *humus* or vegetable-mould formed by their decay, diminishes the evaporation by more than half (53 per cent), or reduces it to less than one-quarter (22 per cent) of that in the open, and thus adds very considerably to the surplus amount of moisture retained in the soil. And later observations have shown that in high mountain forests the evaporation is reduced to a minimum of 9 to 13 per cent of the precipitations, while from 87 to 91 per cent remain in the soil.

Some such natural conservation is, indeed, necessary; otherwise, as von Höhnel's investigations have shown, the large quantities of soil-moisture required by timber-crops for transpiration would often not be obtainable if evaporation went on as rapidly in the woodlands as in the open.

5. **As regards the Feeding of Streams and the Purification of Water-Supplies.**—The above results prove that the effect of extensive woodlands, especially when situated at high altitudes, is to cool the air and reduce its capacity for retaining aqueous vapour, thus tending to increase the precipitations in the form of dew, mist, and perhaps also rain. Whilst these precipitations are taking place the crowns of the trees intercept a large proportion of the total, and by breaking the violence of the rainfall protect the soil mechanically from the danger of being washed away down to lower levels during heavy storms. By the decomposition of fallen leaves and twigs a strongly hygroscopic soil-covering is formed, capable of imbibing and retaining moisture with sponge-like capacity. Rapid evaporation of the soil-moisture is counteracted through the protection afforded by the foliage against direct insolation during the day, and by the mechanical hindrance offered to currents of wind. The crown of foliage likewise prevents the soil from cooling rapidly at night by radiation. The hotter the summer, the more marked are these beneficial effects of the woodlands.

When, therefore, large tracts of country are denuded of woodlands, increase of temperature during the days of summer and rapid radiation of soil-warmth by night, due to complete insolation of the soil by day and absence of any protection from wind, must be the inevitable consequences. But no *a priori* statement can be made that woodlands always increase the quantity of soil-moisture, because local climate, elevation, aspect, and kind of tree and timber-crop are all factors influencing the balance between rainfall and transpiration from the tree-foliage.

Examples of the bad effects of destroying woodlands extensively are apparent in many parts of continental Europe, in Western Asia, in South Carolina, and throughout India and Burma. **In Great Britain and Ireland the effects of the wholesale clearance of woodlands have not been so very marked as elsewhere, owing to the favourable influence exerted on our climate in so predominating a manner by the Gulf-Stream.** Our rainfall, and the dampness of our climate generally, are mainly due to the

[1] Ebermayer's *Gesammte Lehre der Waldstreu*, 1876, p. 183.

warmth of the saturated air-currents accompanying the Gulf-Stream; and the influence that woodlands could have with regard to rainfall in the British Isles is trifling when compared with that chief determining factor.

6. **As regards the Protection of Soil against Erosion.**—In localities having no protective woodlands, heavy rains wash away the surface-soil; torrents and freshets run down the watercourses with great violence, laden with detritus and discoloured with the soil held in mechanical solution; consequently streams and rivers often overflow their banks, devastating large areas of low-lying tracts under cultivation—*e.g.*, as was the case in the Thames valley during the wet summer of 1903. Woodlands, on the other hand, tend to break the violence of the rainfall, and retain for the time being about one-fourth of the total amount on the foliage and branches; the roots of the trees and of the undergrowth help to bind the soil firmly; the rainfall is retained by the vegetable-mould and by the spongy growth usually found on the surface-soil, and thence gradually percolates to the deeper layers, where it is held in reserve, to be finally parted with in being utilised for the feeding of perennial streams having their sources on the wooded slopes. It is therefore a matter of considerable importance that the catchment areas of water-supplies and reservoirs should, if possible, be kept under woodlands. The woods at the same time act as natural filters, purifying the water-supply.

In the alpine districts of Southern Europe the necessity for maintaining *ban-forests* as a protection against landslips, avalanches, &c., long ago, even in the middle ages, became apparent; and legal measures were early adopted for safeguarding the woodlands for the common welfare, in order to protect the lower tracts from the effects of erosion of the mountain soil when sodden with rainfall or melted snow.

7. **As regards General Hygienic Effect on the Atmosphere.**—It is well known that, on the one hand, when large tracts of woodland are cleared for cultivation, especially in tropical and subtropical countries, malarial fever and ague frequently become prevalent; and on the other, that the planting of notorious fever districts—such as the Campagna di Roma and the Tuscan marshes (with the Australian Blue-gum, *Eucalyptus globulus*) and the Russian steppes—has certainly diminished the insalubrity of these localities. But the beneficial effects are probably due rather to the degree of direct insolation of the soil, freely afforded in the one case and counteracted in the other, than to any hygienic property inherent in tree-growth. In such cases, too, stagnating excess of soil-moisture may have been got rid of by transpiration through the foliage, and this would of itself go far towards removing causes of insalubrity; while the ramification of the root-systems of the trees throughout the soil would also naturally help to drain it and to induce a beneficial aeration below the surface. Experience has shown that while woodlands tend to dry the soil in low-lying tracts, clearance of the woodlands often leads to marsh and bog formation.

It is generally accepted that ozone kills miasma in the air and purifies the latter—at any rate, impure air contains little or no ozone: the proportion of ozone is therefore usually taken as the measure of atmospheric quality.

The belief that the woodland air is usually, like sea-air, very rich in ozone, has not yet been satisfactorily proved. Ozone being an allotropic modification of oxygen obtainable by passing a series of electrical discharges through it, it is probable that in woodlands in exposed localities, and especially those at high altitudes where storms and electrical disturbances of the air are most frequent, a greater quantity of ozone may be generated in the atmosphere than in localities less subject to such powerful ozonising influences. Ebermayer's experiments in Bavaria showed that the woodland observatories recorded a much higher proportion of ozone than those in towns; but the percentage of oxygen was at the same time slightly less than in the open in the vicinity of woodlands, while there was no perceptible difference in respect of ozone between coniferous and deciduous woods. Further, the woodland air was found to contain most ozone in winter, which shows that its production could not be due to any chemical action of the foliage; for there are no leaves on deciduous trees at that season, whilst Conifers transpire merely, and do not assimilate. The excess of oxygen is therefore probably due to the comparative freedom of woodland air from the carbonic acid and many other impurities with which smoky air in the vicinity of towns is vitiated, and to the withdrawal of enormous supplies of oxygen from the air for the support of animal life at all populous centres.

Sunlight, however, has the power of decomposing carbonic acid in the presence of chlorophyll, the green colouring matter contained in foliage,—the carbon being absorbed by the plant for its growth, and the oxygen set free. During darkness a contrary action takes place, oxygen being consumed by the foliage, and carbonic acid given off. As, however, particularly in the case of deciduous trees which are in leaf only from spring till autumn, the hours of light far exceed in number those of darkness, the general hygienic effect of trees even in cities and towns—apart from their invaluable æsthetic influence—tends to purify the atmosphere from excess of carbonic acid.

8. **As regards the Agricultural Productivity of Neighbouring Tracts.**—From an agricultural standpoint, a dry season is, so far as regards wheat and other cereal crops, much preferable to a low temperature and excessive rainfall. In the former case, although grain crops may be smaller in quantity, they are usually better in quality; whereas a wet season produces larger crops, but they are generally lower in quality. Moist seasons are, however, when not too wet, advantageous for meadow-crops and pasture-lands.

II. The National-Economic Importance of Woodlands.—The national-economic importance of the woodlands in any given country depends to a great extent on its agricultural and commercial development. There is not, and there never can be, any general standard by which it may be measured. The value of having, or even the necessity for, a large proportion of woodlands therefore varies with the specific conditions of each country; but all over the civilised world timber is one of the few commodities that are constantly appreciating in value. In most countries Agriculture is the main industry; and wherever this is the case, woodlands are of great importance on account of their climatic and physical influence already described. And as was pointed out, their influence, and consequently also their national-economic importance, is all the greater when the climate is hot and dry.[1] Such a state of affairs does not exist in England. Agriculture is no longer the main industry upon which the prosperity of the country depends; and even if it still were, the climatic conditions are such that the destruction of the formerly existing woods has had comparatively little effect on arable cultivation.

To form, however, so far as is possible, some sort of general idea of the national-economic advantages of woodlands, it is therefore perhaps best to consider first of all the actual state of affairs in some of the countries where a large percentage of the total area (see table on p. 44) is wooded and under regular management,—and then to see how the commercial and agricultural industries in Great Britain and Ireland are ministered to by the existing woodlands, and what scope there may be for forming large plantations on waste lands with some reasonable prospect of their proving advantageous and profitable.

A fair idea of the enormous importance of woodlands to the industrial life of a nation is furnished by the United States of America (Bulletin No. 5 of the Forestry Division, U.S. Department of Agriculture, 1892):—

No more convincing argument for the importance of this resource in a nation's economy can be offered than to state the value of the forest products in the United States. The total annual product of wood material of all sorts consumed in the United States may be valued in round numbers at $1,000,000,000, representing, roughly speaking, 25,000,000,000 cubic ft. of wood, or the annual increase of the wood-growth of 500,000,000 acres of forest in fair condition. This value exceeds ten times the value of our gold and silver output, and three times the annual product of all our mineral and coal mines put together. It is three times the value of our wheat crop; and with all the toil and risk which our agricultural crops involve, they can barely quadruple the value of this product yielded by nature for the mere harvesting.

If to the value of our total mining product be added the value of stone quarries and petroleum, and this sum be increased by the estimated value of all the steamboats, sailing-vessels, canal-boats, flat-boats, and barges plying in American waters, and belonging to citizens of the United States, it will be less than the value of the forest product by a sum sufficient to purchase at cost of construction all the canals, buy up at par all the stock of the telegraph companies, pay their bonded debts, and construct and equip all the telephone lines. The value of the annual forest product exceeds the gross income of all the railroad and transportation companies. It would suffice to pay the indebtedness of all the States, if we leave out New York and Pennsylvania, including that of all counties, townships, school districts, and cities within those States (in 1880); and it would more than wipe out the remaining public debt of the United States. In fact, ranking manufactures of all kinds and agriculture as respectively first and second in importance, as far as production of values goes, the forest product occupies the third place. This was the case according to the census of 1880. It is claimed that since then

[1] It has been said, however (Endres, article *Forsten*, in *Handbuch der Staatswissenschaften*, Jena, 1892, p. 607), that such beneficial influence of woodlands on agriculture can only be established in rare cases, because the number of too wet years exceeds that of too dry years throughout Central Europe; and that any beneficial effect ceases when the average local rainfall is over 40 in. It is presumed this applies only to corn production, as dampness of climate (though not excessive wet, as in 1903) is favourable to grass crops and stock-raising.

the lumber industry has enlarged to such an extent as to make its product second, if not first, in value.

The capital employed in merely milling this product, aside from that employed in the harvesting, is roughly estimated at $650,000,000, and there are more than 300,000 people occupied in the direct manufacture of forest and sawmill products alone, not to count the employment afforded by its transportation to centres of consumption and its re-manufacture.

It would lead us through all phases and employments of human life were we to attempt an enumeration of the uses to which forest products are put.

Not only does the forest furnish the material for the construction of dwelling and other structures, our railway consumption of 500,000,000 cubic ft. of timber included, but countless articles of domestic economy and implements necessitate its use. Not only does it yield to two-thirds of our population the fuel to warm their houses and to prepare their food, but it gave us the first means of using our mineral resources, and even now 600,000 tons of the iron product depend upon charcoal. Not only does the wood in its natural form serve our needs, but our ingenuity has invented methods by which we can transform it into all sorts of useful materials, like cellulose, paper, and even silk; while lately it has become possible to prepare from the brushwood a feed for cattle more nutritious than straw and equal to hay.

The *Report of the Secretary of Agriculture*, U.S.A., 1892 (p. 304), gave further information pointing in the same direction :—

We have now less than 500,000,000 acres in forest growth; but even that is neither in good condition nor well managed. We have, therefore, long ago begun to use more than the annual growth, and are cutting into the capital which we inherited at a rate which must sooner or later exhaust it unless we adopt recuperative methods. While there are still enormous quantities of virgin timber standing, the accumulations of centuries, the supply is not inexhaustible. Even were we to assume on every acre a stand of 10,000 ft. B.M. of saw timber—a most extravagant average—we would, with our present consumption, have hardly one hundred years of supply in sight,—the time it takes to grow a tree to satisfactory log size. Certain kinds of supplies are beginning to give out. Even the White Pine resources, "which a few years ago seemed so great that to attempt an accurate estimate of them was deemed too difficult an undertaking, have since then become reduced to such small proportions that the end of the whole supply in both Canada and the United States is now plainly in view."

The annual product of this Pine from the sawmill has reached the enormous total of over 8,000,000,000 B.M., which, if we assume a Pine stumpage of 5000 ft. to the acre—a high average—would require the cutting of 1,600,000 acres annually of their White Pine supplies. Since the three White Pine states (Michigan, Wisconsin, and Minnesota) have a total reported forest area of altogether 60,000,000 acres, it is evident that, even if we allow two-thirds of that area to be in the White Pine belt, and consider this area fully stocked—which it is not—twenty-five years would suffice to practically exhaust the supplies. These figures, crude though they be, leave no doubt that the end of this staple is practically much nearer than we have supposed. All opinions to the contrary may be set down as ill founded.

That the above is no over-statement of the actual condition of affairs is already clearly evident :—

The accuracy of his (Prof. Sargent's) prognostications (in connection with the U.S.A. census of 1880) are now apparent when it is known that their far-famed forests of White Pine timber are about gone, for the United States census report for 1900 states, respecting the White Pine (*Pinus Strobus*): "There is probably 50 billion ft. of White Pine standing in the country. The total amount reported as owned by lumbermen is 16,352 million ft., and the cut in the census year is approximately 7500 million ft., showing that the holdings of lumber companies so far as reported are sufficient to supply the cut for two or three years only."

Three years have gone by, and estimating the cut of White Pine timber since 1900 at even 5 billion ft. annually, this would leave standing in the United States forests barely 35 billion ft. of White Pine timber, an amount just equalling the sawn lumber manufactured from all kinds of timber during the census year 1900, which was 35,084 million ft. (including, of course, the 7500 million ft. of White Pine), as compared with 12,755 million ft. cut in 1870, 18,091 millions in 1880, and 27,041 millions in 1890. The cut of 1900 being, as it appears, nearly three times as much as that of 1870; while the total value of all forest products increased from 60 million dollars in 1850 to 96 millions in 1860, 210 millions in 1870, 233 millions in 1880, 437 millions in 1890, and 566 millions in 1900.

The United States census returns for 1900 also show, as was predicted by Professor Sargent, that the Northern States have now been forced to draw heavily upon the forests of the south and the Pacific for lumber and other forest products, for we find that fourteen Southern and three Pacific States, which in 1880 supplied forest products to the value of but 51 million dollars (a sum less than that of the single State of Michigan, which exceeded 52 million dollars in 1880, and 83 million dollars in 1890), exceeded this amount in 1900 by just 200 million dollars, their total value being 251 millions, or five times as much as in 1880. The increase in some States being very great, advancing in Arkansas in the south from $1,793,848 to $23,958,983, and in Washington in the west from $1,734,742 to $30,286,280. The increase in the amount of lumber sawn being from 3686 millions to 14,743 millions in the south, and from 642 millions to 3900 millions in the Pacific States, making the total amount of lumber sawn in the south and the Pacific 18,643 millions in 1900, as compared with 4328 millions in 1880; showing that the amount of lumber sawn in the south and west for the census year 1900 was in excess of the entire cut of all kinds of lumber manufactured in the United States in 1880, and considerably more than one-half of the total amount of lumber sawn in the United States in 1900.

The cut of southern Yellow Pine timber (including about 1000 million ft. sawn in the west) reached a total of 10,603 million ft., as compared with 7483 million ft. of White Pine, 3420 millions Hemlock (1860 millions in the North-eastern States, and 1560 millions in the west), and 1448 million ft. of Spruce. The southern Pines and Pacific Fir almost exactly equalling the cut of White Pine, Hemlock, and Spruce, the former being 12,339 millions and the latter 12,351 million ft.; so that it is but reasonable to assume that the cut of southern Pine to-day largely exceeds the whole cut of White Pine, Hemlock, and Spruce, and by the time another census year comes around the lordly White Pine, that heretofore dominated all other timber-trees combined in its production of lumber, will have disappeared from the census enumeration as an important factor in lumber production.

This is an object-lesson that should be seriously considered by us, for I greatly fear a critical examination of our Canadian forest lands would show that we too have been running a close race with our neighbours in the rate of forest, and especially White Pine, destruction.—(*Fourth Annual Report of Canadian Forestry Association*, 1903.)

During the twelve years since then the United States have taken very active steps to form timber reserves and to introduce management into the State woodlands and technical instruction in Forestry into universities and agricultural colleges.

In Germany the $34\frac{3}{4}$ millions of acres of woodlands, covering over 25 per cent of the empire, consist of about 43 per cent Scots Pine and 23 per cent of Spruce and Silver Fir (making about two-thirds altogether under Conifers), 15 per cent Beech, 7 per cent Oak (high-forest and coppices), and 6 per cent Copse-woods with Standards, simple Coppices 3 per cent, Alder, Birch, Aspen, Willows, and Osiers 3 per cent (making about one-third under broad-leaved trees). In round numbers, about one-third of the woodlands are in the South German mountain-tracts and the Alps, one-third cover the highlands of

Central and Northern Germany, and one-third are on the North German plains, consisting mostly of poor sand.[1]

Originally, and for a long time, the chief object of administration in the German woodlands was to ensure a sufficient supply of fuel for all local and national requirements. But the vast increase in commercial industry and population in the last thirty years has led to the use of coal and the extension of mining, although wood-fuel is still what is chiefly used for domestic purposes. These economic changes since 1871 have very appreciably affected the uses to which the wood produced in Germany is now put. Whereas formerly it was mostly split up into fuel, it is now mostly used as timber for industrial purposes, and the steady progress in this direction has been as follows :—

State.	1870.		1880.		1890.		1895.		1900.	
	Timber.	Fuel.	Timber.	Fuel.	Timber.	Fuel.	Timber.	Fuel.	Timber.	Fuel.
	%	%	%	%	%	%	%	%	%	%
Prussia	30	70	29	71	47	53	51	49	...	...
Saxony	61	39	75	25	80	20	79	21	82	18
Bavaria	32	68	33	67	46	54	48	52	50	50
Würtemberg	40	60	39	61	54	46	53	47	58	42
Baden	34	66	35	65	42	58	44	56	48	52

And as supplies of timber from Russia, Sweden, Norway, and Austria get dearer and scarcer, the tendency is for the percentage of timber to increase, as compared with that of the wood used for fuel. But extensive and well

[1] No statistics are available to show the woodland disposition as to elevation above sea-level, but Weber (*op. cit.*, p. 20) gives the following synopsis for Austria, Würtemberg, and France :—

Elevation.	Austria.	Würtemberg.		France.		Elevation.
		Broad-leaved.	Conifer.	State and endowments.	Private woods.	
feet.	per cent.	per cent.	per cent.	per cent.	per cent.	feet.
Up to 1000	3·0	6	...	17·2	44·6	Up to 1000
1000-1300		15	7	34·4	19·3	1000-1300
1300-1650	15·5	22	32	13·2	11·8	1300-1650
1650-2000		21	25			1650-2000
2000-2300		23	18	6·0	7·2	2000-2300
2300-2650	25·6	12	11			2300-2650
2650-3000		1	6	7·0	11·8	2650-3000
3000-3300		...	...			3000-3300
3300-4000				6·2	3·3	3300-4000
4000-4650	41·6	...	...	7·8	1·6	4000-4650
4650-5300				3·9	0·3	4650-5300
5300-6000				2·0	0·1	5300-6000
6000-6650	14·3	...	...	1·6	...	6000-6650
6650-7300				0·6	...	6650-7300
Over 7300				0·1	...	Over 7300
Total	100	100	100	100	100	Total

It will be at once apparent from these figures that the great bulk of the woodlands in these countries is to be found at elevations where timber-growing could not be profitable in our now unprotected and wind-swept country.

managed though her woodlands be, Germany is no longer able to supply her growing necessities for timber, and she already has to import over 4½ million tons of wood annually, valued at nearly £15,000,000.

Even in Germany, with its highly organised system of statistics, it is not possible to show clearly in figures what the woodland produce means to the empire's internal trade. But, according to the census of 1875, in addition to £4,150,000 annually spent in the managing, protecting, and regenerating forests in Germany, and in felling, preparing, and handling the produce before it was delivered to the buyer, the timber and other produce of the woodlands directly afforded employment to 583,000 persons (or 9 per cent of all the industrial classes throughout the empire), who were engaged in industries—furniture-making, carpentry, carriage-building, waggon-making, cooperage, sawmills, impregnation works, and osier-weaving—dependent on the forests for their raw material.[1] These 583,000 bread-winners represented about 3,000,000 souls, or nearly one-sixteenth of the total population. And in addition to this, very large sums were also payable for transport by land and water after the rough timber had come into the hands of the buyer. The gross receipts now amount to about £22,000,000, from 35 to 40 per cent of which, or between £7,700,000 and £8,800,000, are expended on management, protection, felling and extraction, and sowing and planting, &c., leaving a net surplus of from £13,200,000 to £14,300,000 a-year, and equal to about 7s. 6d. to 8s. 2d. per acre, though this varies greatly according to the averages for different States (see table on next page).

In his Rectorial Address before the University of Munich in 1889,[2] Prof. Gayer stated that the annual yield in timber from the forests of Germany amounted to about 60,000,000 cubic metres (2,120,000,000 cubic ft.), worth from £20,000,000 to £22,500,000, "so that, reckoning 2 per cent as the rate of interest yielded, the capital value of all the German forests may be assessed at about £1,000,000,000 sterling." If our British woodlands, in area about one-eleventh of those of Germany, were managed like the German forests, they should annually yield about £2,000,000, and would have a capital value of about £50,000,000 at twenty-five years' purchase. The actual returns from, and estimated capital value of, the German forests would be higher if the domestic fuel of the nation were not wood, because a large proportion of the 60 millions of cubic metres consists of wood of good quality and dimensions, which is split into fuel-pieces, although in every respect suitable for timber.

One branch of industry which is only possible in well-wooded districts is the production of wood-pulp and cellulose. The first wood-pulp factory was started in Saxony about 1854, and the first cellulose factory about 1874; and there are now *in Germany alone*, to say nothing of Austria, Sweden, and Norway, over 600 pulp-mills (about half of them in Saxony) using nearly 36,000,000 cubic ft. of wood, and 71 cellulose factories consuming about 30,000,000 cubic ft. And these are still comparatively new industries, capable of enormous expansion, and likely in time to raise the price of

[1] Weber, *op. cit.*, in Lorey's *Handbuch der Forstwissenschaft*, 2nd edit., 1903, vol. i. p. 96.

[2] *Der Wald im Wechsel der Zeiten*, 1889, p. 15.

the softer woods suited for this trade (Willow, Poplar, Birch, Lime, and the softer Conifers).

The extent to which, per 100 acres, labour is required in the German woodlands cannot be fixed. In 1883 Danckelmann estimated that the actual cost of labour necessary in woodlands was, *per acre and per annum*, 2·1 shillings in Prussia, 2·6 in Saxony, 3·7 in Alsace-Lorraine, 5·1 in Würtemberg, and 5·3 in Baden; but these data are apt to mislead, as the two last evidently include extraction (timber-slides and floating) done by Government and repaid indirectly by the buyer. No general average figures are here of much practical use, because the actual outlay must vary greatly according to local differences as to population, industries, prices, &c. Throughout Prussia the average ranged for the year 1880-81 from 3s. 4d. per acre in East Prussia (mostly Scots Pine) to 6s. 8d. per acre in the Rhine Province; and it is said to be about 8s. an acre, or over three days' work, in Saxony.

The average net annual income per acre from the State forests in the chief German States has been as follows (Weber, *op. cit.*, p. 102):—

State Forests		Average net income per acre per annum, in shillings.				
Of	Extent in acres (in round figures).	1877-81.	1882-86.	1887-91.	1892-96.	*Note.*—It should be recollected that all these woodland estates consist for the most part of mountainous land that would otherwise be almost unproductive, and also that much fine timber is cut up into fuel for domestic use.
Prussia . .	6,250,000	3·7	4·1	4·9	5·1	
Bavaria . .	2,100,000	5·6	5·8	7·0	8·3	
Würtemberg .	500,000	10·2	10·8	12·5	12·5	
Baden . .	254,000	9·8	10·5	11·9	14·0	
Saxony . .	374,000	14·2	17·6	18·5	17·1	
Alsace-Lorraine	370,000	8·3	7·7	8·6	10·0	

Notwithstanding the very large acreage that is already under woodlands in Germany, every convenient opportunity is taken to convert waste lands into plantations for timber.

In Prussia, after about 20,000 acres had already been planted in the Eifel district between 1854 and 1861, an Act of 1871 provided for an ordinary budget allotment of over £50,000 a-year for the purchase and planting of waste lands, and since 1895 this has been raised to £100,000, whereby much has been done each year to improve land cultivation, especially among the moors and bogs on the Ems and Weser, in the Lüneburger Heide, and in Holstein. The Prussian Forest Department between 1867 and 1892 acquired 329,850 acres at a cost of about £1,125,000, besides granting substantial bounties for planting by private landowners, and giving in one year (1893) about 32,000,000 plants to owners of woodlands. These endeavours on behalf of the State are further assisted by the provincial administrations, communes, and corporations, as well as by large landowners. Thus the woodlands under the Church Lands Department in Hanover have been increased by nearly 14,700 acres in the last thirty years, and those of the Province of Hanover by about 19,600 acres during the last eight years.[1]

[1] Weber, *op. cit.*, p. 69.

In France, too, the $23\frac{1}{3}$ million acres of woods (17·7 per cent of the whole country) are no longer able to provide for the national requirements in timber, so that about $1\frac{1}{4}$ million tons, valued at over £3,000,000, are annually imported. The reckless destruction of woodlands after the Revolution in 1789 produced such disastrous effects in the Alpine districts that laws were passed in 1860 and 1864 with reference to the correction of the watercourses and the planting of the mountain-slopes. From 1861 to 1877 about 235,000 acres were thus dealt with, at a cost of £570,000; and the effects were so favourable that in 1878 a further plan was prepared for the plantation of over 1,880,000 acres within the next sixty to eighty years, at a cost of £2,880,000 for acquiring land in the Alps, Pyrenees, and Cevennes, and of £6,000,000 for reclaiming and planting it. The rules about expropriation of the land required proving drastic, an amendment was passed in 1882 providing £2,500,000 for purchase and plantation. Altogether, some 416,500 acres have been reclaimed, and a scheme has been approved for continuing work at an estimated total cost of about £8,000,000.

Another great national-economic work in France has been the planting of the barren sand-dunes known as the "Landes," in the south-west, near Bordeaux. There about 110,000 acres were planted (with *Pinus maritima*) by the Department of Public Works; while the Forest Department has since 1862 planted about 36,000 acres, and private owners have been able to cultivate about 40,000 acres. The practical effect of this work has been that the Landes are now one of the best-wooded parts of France, that the climate and the health of the people have become greatly improved, and that these once barren districts have a large and increasing trade in timber and turpentine.

The French statistics show, as must of course be the case in every country, that the value of timber of much the same character and quality varies greatly in different localities, according to their commercial development. The highest returns are obtained near Besançon, an important timber and general trading centre, where the Pine and Fir woods yield an average *gross* return (or *gross* rental value) of £3, 9s. per acre per annum; while around Aurillac, in the southern Auvergne, it averages only 5s. 6d. per acre per annum, owing to the absence of wood-consuming industries and the limitations imposed on timber transport by the prohibitive cost of haulage for long distances by land, when no waterways permit of floating, the cheapest method of transport.

In the State forests of Austria and those that are under State management, amounting to a total of 2,205,317 acres, or rather more than two-thirds of our British woodlands, employment is provided for 18,336 workmen, whilst members of their families are employed to the number of 39,060 persons.[1]

It has been from the Austrian empire that the largest imports of timber have been made into Germany of recent years; but this source of income to

[1] Endres, article *Forsten*, in *Handwörterbuch der Staatswissenschaften*, Jena, 1892, vol. iii. p. 616.

the great landowners is not likely to be long maintained, as the woodlands have been much overworked, and are generally in a more or less exhausted condition. This, of course, means that when Germany becomes deprived of some of her imports from Austria, the competition between England and Germany must become greater for Baltic timber, so that prices will necessarily increase more rapidly than has recently been the case.

Precisely the same differences exist in the United Kingdom with regard to differences in local prices obtainable for home-grown timber as have just been referred to above with regard to gross rent obtained per acre from woodlands in France. Our building and mining operations, our railways, and many of our other industries require vast quantities of timber annually ; and yet there are many parts of the United Kingdom (more particularly in Ireland, the least industrial part of the kingdom) where there are practically no local industries requiring wood as their raw material. For example, most of the Larch produced in the south-east of Ireland is shipped to Liverpool or Cardiff for pit-wood, and as its value is regulated solely by the price obtainable at these ports in competition with foreign imports, it often happens that the landowner only gets about 6d. a cubic foot for Larch that could easily be disposed of at 1s. a cubic foot (and often more) in many parts of England and Scotland. For Scots Pine and Spruce grown along with the Larch in Ireland there is often practically no market at all, *not even as fuel ;* and the same may be said about small thinnings below pit-wood size. Without local industries consuming wood, the value of timber *in situ* therefore usually declines proportionately with the distance and the cost of transport from some assured market. I know a case in which the closure of a mine has had the effect of making good plantations near there lose 50 per cent in their market value ; and I could point to another in which the location of workable seams of the coal known to exist in the neighbourhood would, on mining operations being put in hand, at once raise the value of the mixed Conifer woodlands by at least 60 or 70 per cent.

Despite the difficulty there very often is in disposing of home-grown timber in Ireland, it is nevertheless a fact that while the bulk of the timber is exported as pit-wood to England and Wales (see table below), yet a considerable quantity of foreign timber is imported, though the precise quantity is not ascertainable from published returns. In the thriving inland town of Enniscorthy I found that the local sawmill only used foreign timber. It was found more convenient to buy squares in Dublin and convert them to local requirements than to buy home-grown timber in the neighbourhood. The foreign wood was easier to mill and could always be got at short notice, whereas local supplies could not always be depended on, and generally involved more work, and sometimes also a lot of worry.

The extent to which our existing three million acres of "woods and plantations" directly and indirectly provide employment for the rural population cannot be estimated. No data are available for Great Britain, and those for Ireland are only as follows :—

Plantations and fellings in Ireland from 1st July 1901 to 30th June 1902.	Area.	Total No. of trees planted.	Number and description of trees planted and felled (including thinnings).										
			Larch.	Fir.	Spruce.	Pine.	Oak.	Ash.	Beech.	Sycamore.	Elm.	Other trees.	Mixed trees. (No. of each kind unspecified.)
Planted . . .	acres. 935	1,571,355	1,007,577	235,650	122,950	66,600	31,206	18,100	14,162	22,010	5,700	14,900	32,500
Felled (including thinnings)	1,246	1,201,046	390,098	278,785	64,147	53,403	126,740	45,551	67,824	30,500	27,158	2,343	114,497

Number of Trees Felled, and Uses to which Applied.

	Total.	Propping* (Pit-wood).	Sleepers.	Paling.	Spools.	Fuel.	Furniture and building purposes.	Carts, waggons, &c.	Clog soles.	Ship-building.	Telegraph and telephone poles.	Other specified uses.	Unspecified.	
													"Used locally."	"Exported."*
Number of trees felled, and uses to which put	1,201,046	440,741	23,292	21,261	1200	35,955	20,732	3307	5380	22,450	...	9106	177,414	440,208

* Pit-props are exported.

But to attempt to estimate what might or might not be the case if our woodlands were managed systematically as in France or Germany, can be of little practical interest, because our economic conditions are so entirely different from those obtaining on the Continent that no reliable comparison can be made, either on the basis of woodland area, consumption of timber, or population. Prices in England are usually considerably above those obtained in Germany; but, as above shown, there are places in the United Kingdom where prices fall very far below the average values in England,[1] and are

[1] Approximate values of timber, 1902 (from *Minutes of Evidence, Departmental Committee, British Forestry*, 1903 [Cd. 1565], p. 171):—

	Per cubic foot. *s.*	*d.*		Per cubic foot. *s.*	*d.*	
Oak under 15 ft.	1	3	Spanish Chestnut	1	6	and upwards.
„ 15 to 20 ft.	1	8	Horse Chestnut	1	0	„
„ 25 to 50 ft.	2	0	Walnut	2	0	„
„ 50 ft. and upwards	2	6 and upwards.	Lime	1	6	„
			Hornbeam	2	0	„
Ash under 15 ft.	1	0	Sycamore	1	6	„
„ 15 to 25 ft.	1	6	Willow	1	3	„
„ 25 ft. and upwards	2	0	Plane	1	0	„
Elm under 15 ft.	0	6	Poplar, Italian (black)	0	10	„
„ 15 to 25 ft.	0	9	„ Lombardy	0	3	„
„ 25 ft. and upwards	1	0	Birch	1	0	„
Beech under 15 ft.	0	9	Maple	0	9	„
„ 15 to 25 ft.	1	0	Cherry	0	9	„
„ 25 ft. and upwards	1	6	Acacia	1	0	„
Larch Fir	9d. to 1	2	Box	2	6	„
Scotch Fir	6d. to 0	9	Holly	2	0	„
Spruce Fir	4d. to 0	6				

Compared with these average prices for England, those obtainable *in somewhat favourable localities* in S.E. Ireland show a great reduction:—

Prices obtainable *per ton weight* for timber: there is practically no market for small thinnings.		
Co. Wicklow.		Co. Tipperary.
Rathdrum.	Ashford.	Carrick-on-Suir.
Ash and Sycamore, 18s. to 24s. Larch and Oak, 12s. to 16s. Scots Pine, Spruce, and Silver Fir, 6s. to 10s.	Larch, 12s. net. Scots Pine, Spruce, and Oak, 8s. net. Silver Fir, 7s. net.	Larch, 9s. to 12s., Scots Pine and Spruce, 7s. to 8s. } down to 3 in. diameter. Scrub-Oak (for pit-wood, only occasionally saleable), 6s. to 8s., down to 3½ in. diameter. (Timber sold standing.)
Co. Waterford.		
Lismore.	Curraghmore.	Gurteen-le-Poer.
Ash, 16s., Oak, 14s., Elm, 10s., } down to 6 in. diameter. Beech, 14s., down to 5 in. diameter. Larch, 10s., „ 3 in. „ Scots Pine, Spruce, Silver Fir, 8s., } down to 3 in. diameter.	Larch, 9s. 6d. to 12s. 6d. Scots Pine, 6s. to 9s. 6d. Spruce and Silver Fir, 6s. } Felled and delivered in the wood. Hardwoods (of pit-wood size only), 6s. a ton. All big Larch and hardwood timber are required for estate work.	Larch, 10s. to 12s., Scots Pine, 5s. 6d., } down to 3 in. diameter. Elm and Beech, } 6s. 6d. to 7s., down to 5 in. diameter. (Timber sold standing.)

probably also below those readily obtainable in most parts of Germany. And though wood is cheaper in Germany, its production is also far cheaper. Labour is cheaper and more easily obtainable, with the additional advantage of a sort of hereditary knowledge of woodmen's work; plants are cheaper; and there is the benefit derived from doing things on a wholesale scale. But, above all, there exists the absorptive market prepared to utilise everything, including small thinnings in large quantities—and *that* we have not got.

A very good example of this—and of how misleading such data may sometimes be—is given in para. 8 of the recent *Report on British Forestry*, 1903, where the Committee say that—

8. Dr Schlich gives corroborating evidence from the Continental forests, where accurate book-keeping has long been practised. As an example, he says, referring to Saxony: "I have selected one of the ranges which is by no means the best. It is a district called the Anthonsthal Range, an area of 4072 acres, managed by a highly trained forester, situated in the Erzgebirge, between an elevation of 1500 and 2700 feet. . . . Distinguishing between four quality classes of soil, and calling 1 the best and 4 the least, the average quality is 2·7; it is therefore between second and third quality. The species grown there are 93 per cent Spruce, 3 per cent Silver Fir, Scottish Pine, and Beech, and 4 per cent blanks for certain reasons. The growing-stock in this forest in 1839 averaged 2128 cubic ft. per acre, and in 1893 it was 3276 cubic ft. The receipts per acre were 48·3s. and the expenses 10·3s., the net receipts being 38s. per acre per annum." This statement refers to land not worth more than 4s. per acre per annum for agricultural or pastoral purposes.

Now, the splendid result of 38s. per acre simply proves that the Anthonsthal forest is situated in a highly industrial centre, where there is a constant demand for the wood supplied by it. This net income of 38s. per acre per annum is $2\frac{1}{4}$ *times as much as the general average was for Saxony in* 1892-96, $4\frac{1}{2}$ *times as much as the general average for Bavaria, and over* 7 *times the general average for Prussia* (see table on p. 85). The accuracy of the book-keeping and the systematic and scientific management are no doubt quite as good in Prussia, Bavaria, and the rest of Saxony as in the Anthonsthal forest; but the local industrial balance of supply and demand is doubtless very different in all less favoured places. Further, it must be recollected that the above return of "*expenses*, 10·3s." are exceptionally low. For the whole of the Saxon State forests the average was 39·2s. per hectare (Weber, *op. cit.*, p. 95), or 16s. per acre; and at Anthonsthal they therefore appear to have been more than 33 per cent below the general average for all Saxony.

Some parts of Britain can show (on a very small scale, it is true) finer examples of profitable Forestry than Anthonsthal—*e.g.*, the Douglas Fir plantation of 8 acres at Taymount (seven miles from Perth), for which crop the owner refused an offer of close on £200 per acre at forty years of age;[1] yet there are many parts of the United Kingdom where, owing to heavy cost of transport to any favourable market, similar woods would not be worth a half, or even a third, of that sum. But in any case, it is certainly very misleading to put forward exceptionally favourable examples as if they were merely average results, due solely to good management of the timber-crops,

[1] See Part II., chap. ii., *Douglas Fir*.

without at the same time candidly stating the facts with regard to other woodlands less favourably situated.

No rational comparisons can be drawn at present, because the economic conditions are so totally different, between British and Continental woodlands. In France and Germany wood forms the main article of fuel used for domestic purposes, and many trades have sprung up which are dependent for their raw material on woodlands in the immediate vicinity; and the result of these conditions is that there is a constant market not only for timber but also for fuel, and for all the various classes of small stuff cut from woods and plantations in the shape of early thinnings. So much so is this the case, that it sometimes proves profitable to have the roots of old trees grubbed up and sold after the mature timber-crop has been felled and cleared away. In Austria, in 1878, a law had even to be passed prohibiting grubbing of stumps where shifting sand was feared. Unfortunately landowners possessed of woodlands in Great Britain and Ireland have no such favourable conditions for disposing of their wood; and the only hope there can be that many of the existing woods and plantations might (under better management) prove much more profitable than at present lies in the great probability there is that timber will, in the near future, become considerably more valuable than it now is. It is only on very few estates indeed that any exact system of book-keeping has been maintained relating to the various outgoings and incomings concerning the separate woods and plantations; but even if such were available, which is not the case, no true estimate could be formed from them as to the return in timber and money which might be looked for if the woodlands had been continuously managed on purely business principles from the time of their formation until their maturity.

Even the furniture factories in Bucks, founded and developed in connection with the local beech-woods during centuries past, have at last gradually become dependent on foreign timber to a large extent. Moreover, the great work abroad with regard to timber supplies was mainly to introduce organised administration into the woodlands, the free gift of nature; whereas our free gifts of the same kind were destroyed long ago, and any possibility of now restoring them in part means facing a vast, and for a long time an unremunerative, expenditure in planting waste lands much deteriorated through exposure to sun, rain, and wind.

The question of the planting of waste lands throughout Great Britain and Ireland seems one that is really of greater importance than the better management of such of our existing woodlands as are intended to be worked for profit and not mainly for sport or ornament—a mere fraction, and an unknown quantity. To no small extent the productivity of the woods of this last class over thirty years of age has been so much impaired by injudicious over-thinning that they have sustained permanent damage, which can only be rectified when the present crops are cleared and their place has been taken by new plantations.

Apart from the difficulty of finding profitable sale for small thinnings and encouraging wood-consuming industries in thinly populated rural districts, there is no reason, so far as soil and climate are concerned, why trees should not, over large areas of poor land, be grown and managed as crops of timber according to the systematic methods adopted in France and Germany.

The hardwood trees (Oak, Beech, Elm, Ash, Sycamore, &c.) in many parts attain fine dimensions and vigorous growth, while softwoods (Willow, Poplar, Birch, Alder, &c.) also thrive in the lower and moister situations proper to their natural requirements. But both in the present and for the future it is mainly the coniferous trees (Larch, Pines, Spruce, Firs) that are likely to receive most consideration when planting for profit is being undertaken on any extensive scale, whether the investor be a private landowner or the State.

Even under the best possible management, however, any great increase in the present woodland area throughout the United Kingdom must go hand in hand with the encouragement and improvement of existing wood-consuming industries, and the creation and fostering of new ones, before it is possible that any large investment of national capital in this direction is likely to have any fair chance of assuring direct monetary profit. A great impetus would at once be given in this direction if the proposed fiscal changes, likely to be soon considered seriously as our future national and imperial policy, should include the fixing of an import duty on all wrought or partially converted timber imported from any *foreign* country in any other shape than round logs or rough-hewn squares. Such a change would at once stimulate the sawmill business, and would encourage the growing of wood for profit in a way that has never been done since the import duty was taken off foreign timber. This, together with facilities for obtaining the loan of the necessary capital on easy but fair terms, would be more likely than anything else to stimulate planting on a large scale; and this would help to provide employment for part of the rural population during the late autumn and early spring, when most other rural industries are slack and the labouring population is unfortunately in want of employment. Planting is a kind of work, too, in which boys and girls can assist wherever adult labour is scarce; and as a matter of fact, the deft hands of young boys and girls are best suited for manipulating the plants and fixing the earth round their roots. Without attempting the impossible task of framing any really reliable forecast as to the economic results of a state of things which does not at present exist, it is at any rate safe to say that anything which would undoubtedly help to provide employment for the poor and steadily diminishing rural population seems worthy of consideration by Government.

It is not possible that any such large scheme of planting as appears desirable for national-economic reasons in Great Britain and Ireland can be undertaken by private landowners. There seems to be a consensus of opinion that the sooner steps are taken in the direction of extensive planting the better for the country and for the people; but this national work should either be undertaken directly by Government, or else practical assistance and encouragement should be held out to induce landowners to plant. Very few of the latter, except they also own rich estates or coal-mines, &c., have the ready money necessary for making immovable investments of this sort, bound to remain unremunerative for thirty to forty years; and Government has hitherto offered no inducement whatever in the way of making advances on easy terms, repayable as to interest and capital only when the timber crops are reaching maturity, or of remitting rates and taxes on the land planted, or of granting partial relief as regards death and estate duties, and enabling such charges on wooded portions of estates to remain unpaid till the timber-crops become mature and marketable.

The necessity for State assistance is a chronic drawback to planting for profit. Early in the last century this was just as much the case as it now is. Even then, although all the timber, bark, and small material from the copsewoods was easily sold at good prices, want of funds prevented extensive planting of waste lands.

Such lands, it must be owned, are sufficiently abundant, but the great expense and slow returns of planting are inconvenient to the majority of land proprietors. . . . The expense of planting is immediate and certain, the profit distant and precarious.[1]

This is precisely what the recent Committee on Forestry has reiterated. The main drawback to planting is, and has always been, and probably always will be, want of funds; all the other obstacles can far more easily be removed.

But even if substantial inducements could be offered by Government to private landowners, it would not necessarily follow that the plantations thereafter formed would be managed upon more business-like principles than are the existing woods and plantations. The State is the only possible landowner that can be expected to create large compact blocks of woodlands in the United Kingdom, to be managed on sylvicultural principles, with the twofold object of providing supplies of timber in the future and of fostering and encouraging rural and wood-consuming industries. If this be a duty at all, it is the duty of the State, and not of the private landowner. The State is the only landowner that never dies nor is called upon to pay estate and succession duty, and it is the only landowner that can make large investments without being compelled to desire quick returns in the shape of income; hence the State is the only landowner that can be sure of remaining free from the temptation to thin timber-crops at an early age and to a great extent—or, in short, that can afford to grow the best classes of timber upon rational principles.

Considering the present condition and the future prospects of the timber market, crops of coniferous trees are those most likely to be planted on any large scale for profit, whether by the State or by private landowners. The hardwood trees will always, on account of their beauty, be grown in the vicinity of country houses, and softwoods on low-lying wet lands. From its rapid, early growth, the value of its timber for agricultural and other purposes, and the fact that it is of use and can usually be easily disposed of at all sizes, from that of the small pole upwards, Ash, usually the most valuable and profitable of the hardwoods, is certain to receive a fair amount of attention in all places where it can be grown free from fungous black-rot. But as regards Forestry on business principles, there can be very little doubt that in general the main crops will be formed for the most part of coniferous

[1] *Quarterly Review*, 1813, vol. x. p. 9.

trees. Our soil and climate are suitable for their growth, and they have various advantages as compared with crops of hardwood trees. They can be grown on poorer land; they become marketable and reach maturity earlier than crops of Oak, Beech, or Elm; they yield heavier crops of timber, and even though their wood fetches a less sum per cubic foot than is given for hardwoods, yet coniferous crops may, on the whole, be regarded as more profitable than broad-leaved trees, whether hardwood or softwood, on any large scale.

Our Waste Lands undoubtedly offer a wide field for planting; but it is impossible to say in any general way (as *has* been stated) that "*land yielding a smaller net rental than* 8*s*. *an acre*" for agriculture or pasture will now pay better under timber. The reason why any such statement must be misleading is, that favourable local opportunity for disposing of wood at a profit is a main factor entirely overlooked, or at any rate *presumed,* in the actuarial calculations. And unfortunately the favourable local market is often wanting.[1] Before any proper survey has been made, it is extremely difficult to express any reliable opinion as to the extent to which timber can at present be grown with a fair prospect of profit, the *sine qua non* of such a business concern being the ability to prove the probable realisation of a direct monetary profit. For example, in 1885 it was estimated "that about 2,000,000 acres of the total waste land" of Ireland was plantable;[2] but if one applies the true test of *a reasonable prospect of direct monetary profit* to this estimate, it seems to be far too sanguine. The south and west winds from the Atlantic prevailing for a great part of the year are so strong, and the absence of natural shelter is usually so entire, that great stretches of waste lands, otherwise suitable for planting, could not at present be made to produce profitable crops of timber, even allowing for a considerable rise in the market value of timber in out-of-the-way places during the next thirty to forty years. Eliminating from the total the 1,027,927 acres occupied by "water, roads, fences, &c.," the *waste lands* in Ireland aggregate 3,779,640 acres, of which 1,124,111 acres are *turf bog*, 428,662 acres *marsh*, and 2,226,867 *barren mountain-land;* and a recent examination for the purpose has shown that only about *one-fifth*, or 755,000 acres (1180 square miles) of this waste area is capable of being planted with any first crop of Conifers likely to be directly profitable as a monetary investment. But it was expressly noted, at the time this very much reduced estimate was made, that it included a considerable extent of poor, furze-grown land, really little or nothing better than waste land in its present condition, and only fit for planting, which is probably classed under *grass* lands in the statistical returns issued by the Department of Agriculture.

Applying this same ratio of one-fifth of the total nominal area as plantable with a reasonable chance of direct monetary profit, this would show that the

[1] Let us take wood-pulp, for example. Our imports in 1902 were 525,799 tons (£2,398,215), and in 1903 they were 576,153 tons, worth about £2,500,000. Spruce is one of the good woods for making cellulose, and in Ireland I have seen some thousands of acres where Spruce is practically unsaleable. But there are few or no localities with the requisite 2000 to 3000 acres of Spruce near at hand to supply a pulp-mill continuously with 35 to 50 tons of raw material daily; and less would hardly pay there.

[2] *Ireland, Industrial and Agricultural*, 1902, p. 323.

extent of planting at present likely to prove profitable is limited to about 3,342,000 acres, or about *one and one-tenth* times the existing area now classed as "woods and plantations":—

	Waste land.	Probably plantable with a fair chance of profit.
	Acres.	Acres.
England . . .	2,305,823	461,164
Scotland . . .	9,374,512	1,874,902
Wales . . .	1,250,813	250,162
Ireland . . .	3,779,640	755,928
Total . . .	16,710,788	3,342,156

A large proportion of the waste lands are above the 1000 ft. contour line, and in the open, wind-swept, unsheltered condition of the country very little of this higher land can possibly be planted at present with any fair chance of profit; while there is also a large percentage of *peat-bogs* where no timber crops will thrive until the bog is cut away so far as to allow the young trees to get their roots down into the mineral soil. It is just as impossible to grow timber with profit on deep bogs as on bare, wind-swept mountain slopes having little or no soil left on them.

If a great national scheme of planting were to be adopted with a view to supply part of our future requirements in timber, the cost of planting these 3,342,000 acres of waste land would probably be about £6 an acre for draining, fencing, and planting, exclusive of the cost of acquiring the land and maintaining the woods and plantations. This would mean a total actual outlay of about £20,000,000 (disregarding compound interest), which could be spread over the next thirty to fifty years. Of course if such woodlands were once created in large compact blocks to anything like the above extent, no doubt the shelter thus provided would enable future generations to add to their area, if found desirable; but in the face of the present unfavourable wind-swept condition of our waste lands, and of the want of wood-consuming trades except at industrial centres, the above seems a fair estimate of what might be planted (with a reasonable expectation of profit) during the course of the next fifty years. This estimate does not include every piece of poor pasturage and apparently waste land suitable for planting, because for planting with a fair chance of profit it is essential to form large compact blocks of woodland. Small scattered plantations of 20, 30, 40, or 50 acres can neither be made nor managed so economically as large compact blocks of 500, 1000, or 2000 acres, for between **Sylviculture** and **Arboriculture** there is just the same sort of economic difference as exists between manufacturing on a large and on a small scale.

Most of the 755,000 acres of waste lands in Ireland suitable for planting with a fair chance of direct monetary profit appear to have been formerly cultivated, before the great flow of emigration commenced after the potato-famine in 1846-49. The old stone dykes are still standing, though more or less in disrepair, while ridge and furrow are still often traceable. Such land might again be easily reclaimed from the waste and unprofitable condition into which it has fallen during the last fifty years; but with emigration and depopulation still going on rapidly, any such reclamation of poor wasted tracts can scarcely be hoped for. And in the Scottish Highlands the circumstances are frequently very similar: the hill-pastures are poor and deteriorated, and bogs are often extending. Under such circumstances the plantations of quick-growing coniferous timber-crops likely to contribute materially to our national welfare in the future seems to be the best, and often the only, way of utilising these poor waste lands.

The question of the probable money profit obtainable from judicious planting is a difficult and thorny one to handle. Wildly sanguine estimates have often been made—not only long ago, but even down to the present time—about the profit of transforming vast stretches of waste land into woodlands. It is easy to juggle with figures, and make a plausible show of certain profit two or three generations hence; and there is a sort of fascination about calculations of this sort. About a hundred years ago the Bishop of Llandaff sent a paper to the President of the Board of Agriculture, estimating that 379 acres of Larch then planted by him would (at 5 per cent interest on the planting and the rent of the land) cost him £13,798 at sixty years of age, whilst the returns "will, I consider, upon the most moderate computation, amount to £150,000, if the commerce of the country and the price of foreign Fir-wood continue for sixty years without diminution."[1] It would be interesting to be able to compare the actual returns with this sanguine estimate, because we know that the hopes then entertained about Larch were shattered by the epidemic canker-fungus.

The difficulty found in attempting to estimate the direct monetary profit attainable by planting largely on poor pasturage and waste lands is that it always refers more to a *possibility* than to a *probability.* Considering the long period of time elapsing between the sowing and the reaping of harvests of timber, and considering the violent gales (usually after heavy rainfall) that sweep over most parts of our islands every few years, there must always necessarily be an element of uncertainty as to the future monetary results of planting. This danger from extensive windfall is far greater here than in the interior of continental Europe, though actual experience has often shown that land no longer profitable under arable cultivation or pasture will often yield favourable returns under timber.

Considering the now well-known fact that the world's demands for timber are growing annually, while the area of possible production is diminishing yearly, no elaborate arguments are needed to indicate the probability that timber may have a greatly increased value thirty to forty or fifty years hence. But beyond this it is not very safe to go.

[1] *Quarterly Review*, 1813, vol. x. p. 17.

The available data are much too uncertain to be really of practical use for *reliable* actuarial calculations. The apparent exactness obtained on paper proves often purely fictitious in actual reality. Notwithstanding the satisfaction to be derived from making what seem reasonable and exact estimates of expenditure and income, and showing the net profit available on the total investments with interest calculated at 3 per cent, and the still larger profits shown if $2\frac{3}{4}$ and $2\frac{1}{2}$ per cent be accepted as the rate of interest upon which such calculations are based, any great national scheme of planting, such as seems desirable in the interests of the country, should be considered from a broader economic standpoint than by making interesting calculations with hypothetical data as to future thinnings, and the yield and value (when mature) of crops of timber not yet planted. A financial balance-sheet of this suppositititious nature is absurd in face of the fact that in many thinly populated tracts Scots Pine, Spruce, and Silver Fir timber is not saleable in any large quantity at anything like remunerative rates, and that no profitable market exists for early thinnings yielding only small material.

Nor are the available data sufficient to enable any really reliable actuarial calculations to be made for the purpose of endeavouring to prove by figures whether, and precisely to what extent, the best chance of profit may lie in the customary British habit of over-thinning (*i.e.*, partial premature clearance) of the timber-crops, or in managing them conservatively with a view to obtaining the largest return on clearing the mature crop. Various conditions, always liable to change, are involved in calculations of this sort, which can really only be considered as having rather a theoretical and general interest than any exact and practical value. On an Irish estate situated in a part of Co. Waterford, with a favourable market for timber, where the woodlands extend to about 1200 acres, consisting mostly of plantations of Larch, Scots Pine, and Spruce under forty years of age, those of about twenty years old predominating, a more or less regular system of management has been adopted, though it is not adhered to on any really fixed plan. This method consists in thinning freely all the young plantations at about fifteen years of age, some of the biggest poles being cut out as well as all smaller ones. Then, at about twenty years of age, the plantations are again thinned rather freely, and once more at about twenty-seven years of age, and then finally clear-felled when about thirty-three to thirty-five years old, after which they are replanted (with Larch chiefly, at 4 by 4 ft.) This system is based on the two main facts (1) that Larch is the only timber which can at present be easily or profitably disposed of, and (2) that the only favourable market at present is for pit-wood (down to 3 in. top diameter, for export to Wales).

Countings made (1903) on two sample areas *on good land* showed a crop of only about 725 trees per acre at twenty-eight years of age (or not much more than one-fourth of the number originally planted, 2722, at 4 by 4 ft.), of which the larger poles girth from 20 to 24 in. measured at breast-height. This is, of course, a system that can only, with any degree of safety, be ventured on in sheltered situations, because otherwise such heavy thinnings as are made would usually result in serious damage from windfall during severe gales. The landowner kindly gave me the following data as to the average amount of pit-wood timber obtainable per statute acre under his system :—

First thinning	at about 15 years of age	yields about	580 trees	= 20 tons	per acre.
Second	" 20	" "	500 "	= 25	"
Third	" 27	" "	380 "	= 20	"
Fourth	" 30	" "	360 "	= 30	"
Final clearance	" 35	" "	240 "	= 20	"
	Total . . .		2060 "	=115	"

The prices obtainable for the timber, sold standing and measured down to 3 in. top diameter (over bark; $2\frac{1}{2}$ in. free of bark), is 10s. to 12s. per ton for Larch and 5s. to 5s. 6d. for Scots Pine. The cost of replanting at 4 by 4 ft. averages from £4, 10s. to £4, 15s. per statute acre, while wire-fencing against rabbits is fortunately not necessary.

Under such circumstances as the above the private landowner may often find it to his profit to thin early and heavily, to force on the growth in girth of the trees and obtain frequent returns from the capital invested in the land and the plantations. Much less capital as to the growing-stock is required in working with a forced, premature rotation of thirty-five years than would be represented by timber-crops harvested only at fifty or sixty years of age, and the landowner is much more likely in the former case to have substantial returns during his own lifetime from the investments he himself may have made.

As regards woodlands owned by the State, the case is different. These ought to be managed on national-economic principles, but no such considerations hamper the freedom of action of the private landowner.

The **Direct Monetary Profit** in the above case, calculated on such data as were available, would appear to be as follows :—

	£ s. d.		At 3 per cent interest. £ s. d.	At 4 per cent interest. £ s. d.
DEBIT.				
Planting, at £4, 15s. per acre, amounting in 35 years to			13 7 3	18 14 10
Rent of land, at 5s. per acre per annum, " "			15 2 3	18 8 3
			28 9 6	37 3 1
CREDIT.				
Thinnings—				
(1) At 15 years, 10 tons Larch at 10s. .	5 0 0			
10 " Pine " 5s. .	2 10 0			
	7 10 0	accruing in 20 years to	13 10 10	16 8 8
(2) At 20 years, $12\frac{1}{2}$ tons Larch at 10s. .	6 5 0			
$12\frac{1}{2}$ " Pine " 5s. .	3 2 6			
	9 7 6	" 15 "	14 12 1	16 17 6
(3) At 27 years, 10 tons Larch at 11s. .	5 10 0			
10 " Pine " 5s. .	2 10 0			
	8 0 0	" 8 "	10 2 8	10 18 11
(4) At 30 years, 15 tons Larch at 12s. .	9 0 0			
15 " Pine " 5s. 6d. .	4 2 6			
	13 2 6	" 5 "	15 4 3	15 19 4
Final clearance—				
At 35 years, 10 tons Larch at 12s. . .	6 0 0			
10 " Pine " 5s. 6d. .	2 15 0			
	8 15 0		8 15 0	8 15 0
			62 4 10	68 19 5
Apparent profit			33 15 4	31 16 4

This apparent profit represents a gain of 11s. 2d. per acre per annum on a calculation made at 3 per cent, and 8s. 7½d. per acre per annum on a 4 per cent basis, in addition to the annual rent of 5s. per acre—or a total net annual rent of 16s. 2d. and 13s. 7½d. respectively. The calculation presumes, however —*which cannot be the case in reality*—(1) that no outlay is incurred in beating up blanks after planting, (2) that the income from all the thinnings and the final clearance are *net* returns, (3) that the replanting of the land can take place immediately after the mature crop is cleared, (4) that no cleaning or weeding is necessary at any time before the first thinning takes place at fifteen years of age, (5) that the annual value of the shooting is equal to the rates, &c., levied on the land, and (6) it makes no provision for the cost of supervision and tending by the forester, for the repair and maintenance of fences, or for contingent expenses of any sort. It is, therefore, not at all a trustworthy sort of calculation, although as fair as can be made with the data available.

Making a similar calculation with regard to the **forecast of a 2000 acre mixed Conifer plantation on good plantable waste land favourably situated for the disposal of timber,** I have arrived at the following estimate :—

			At 3 per cent interest. £	At 4 per cent interest. £
DEBIT.				
Draining, fencing, planting, at £7 per acre (£14,000),		amounting in 40 years to	45,668	67,214
Rent of land and rates, &c., at 2s. per acre (£200),		" "	15,080	19,005
Forester, at £60 per annum,		" "	4,524	5,701
			65,272	91,920
CREDIT.				
Shooting, at 3d. per acre per annum (£25), amounting in 40 years to			1,885	2,375
Thinnings—				
(1) At 20 years—	£			
200 poles per acre, worth 2d. each (£1, 13s. 4d. per acre)	3,333⅓			
Less cost of thinning at 4s. 4d. per acre	433⅓			
	2,900	amounting in 20 years to	5,237	6,354
(2) At 25 years—				
150 poles per acre, worth 3d. each (£1, 17s. 6d. per acre)	3,750			
Less cost of thinning at 3s. 6d. per acre	350			
	3,400	" 15 "	5,297	6,123
(3) At 30 years—				
100 poles per acre, worth 4½d. each (£1, 17s. 6d. per acre)	3,750			
Less cost of thinning at 2s. 6d. per acre	250			
	3,500	" 10 "	4,703	5,180
(4) At 35 years—				
100 posts per acre, worth 6d. each (£2, 10s. per acre)	5,000			
Less cost of thinning at 2s. 6d. per acre	250			
	4,750	" 5 "	5,506	5,779
Final clearance—				
At 40 years—				
1000 trees per acre, worth 9d. each, sold *standing* (£37, 10s. per acre)	75,000		75,000	75,000
			97,628	100,811
Apparent profit		Gross	32,356	8,891
		Per acre	£16 3 6	£4 8 10

This apparent profit of £16, 3s. 6d. per acre at a 3 per cent calculation shows a profit of 4s. $3\frac{1}{2}$d. per acre per annum (or 6s. $3\frac{1}{2}$d. total rent), while the £4, 8s. 10d. per acre at 4 per cent shows a profit of $11\frac{1}{4}$d. per acre per annum (or 2s. $11\frac{1}{4}$d. total rent). But while only estimating 1550 poles and trees as saleable (out of a total of 2722 per acre planted at 4 by 4 ft.), it presumes that no charges are incurred till the twentieth year, and that 200,000 small poles (suppressed and unhealthy only : *true thinnings*) of mixed Conifers (Larch, Pine, Firs) could be disposed of even at the low average price of 2d. each. In no rural district in such a locality could the existing market absorb anything like this quantity ; because, even for Larch, there is little sale except for good stout poles of pit-wood size.

In the above estimate I have tried to be as fair and impartial as possible. It shows, as I believe to be the case, that the direct monetary profit which may reasonably be expected from very extensive planting on poor waste lands is hardly sufficient to induce any but very wealthy and magnanimous landowners to make large investments of this nature, and that the State is the only landowner properly qualified to undertake the timber-growing business. But for the rich landowner there are other considerations than mere monetary profit. There is also the pleasure of seeing the gradual growth of plantations,—a pleasure which continues and increases long after he may have become unable to take any further active part in shooting and other outdoor sports.

Failures, however, convey useful lessons as well as successes ; and the most complete failure regarding any attempt to form profitable plantations on poor waste land for which accurate details are available is that of the Knockboy Plantations on the west coast of Ireland.

Knockboy Plantations.—In 1890 an area of 960 acres near Carna, in Connemara, was acquired by the Irish Government with a view partly to experimental planting and partly to the provision of employment for the people. The property was placed under the Irish Land Commission, which spent nearly £2000 in draining, fencing, and planting. On the formation of the Congested Districts Board, Knockboy was transferred to the new Department, which at once entered on Forestry operations. The first report of the Department observed that "if the trees grow in this exposed situation close to the shores of the Atlantic, it will demonstrate that much of the waste lands of Ireland can be turned to profitable account." This was, indeed, quite true, for a rockier and more wind-swept place than Knockboy could hardly have been selected as a test of planting.

Between the autumn of 1891 and the spring of 1894 about half a million broad-leaved trees and nearly two millions of Conifers of different sorts had been planted. By 1895 the plantations were already seen to be an utter failure. Most of the broad-leaved trees were then dead or dying—"*only a few Alder here and there are doing well*" ; and most of the Larch, Firs, and Pines were also either dead or moribund, though it could be said that "*Austrian Pine has done fairly well*," and that "*Scotch Pine . . . in some places . . . have done fairly well, in others they look weedy and lanky*," and that the dwarfish "*Mountain Pines . . . have done best of all ; they look very* *well. It should be noted that they have only been planted lately.*" All the more valuable kinds of trees, planted with a view to profit, were dead or dying, the hardy Scots Pine was growing poorly, and only the coarse-grained Austrian Pine and the stunted Mountain Pine (which never attains large dimensions as a timber-tree) seemed to be making any progress. In 1896 it was considered "*not desirable*" to plant any more, "*pending further experience.*" In 1898 it was decided not to incur any further expense, and in subsequent reports of the Board no mention is made of Knockboy. The appendix to the report for 1901 states that the total outlay of the Board on Knockboy to the year 1900 amounted to £8703, 18s. 2d., while the receipts were £24, 4s. Thus the total expenditure on this complete failure was upwards of £10,500. The Congested Districts Board has since then limited its Forestry operations to supplying small quantities of trees gratis to small occupiers wishing to plant for purposes of shelter.

Sport is really also a matter of national-economic importance in Great Britain and Ireland, where so many of the existing woods and plantations have originally been formed, and have always been managed, mainly with a view to the shooting they furnish. Improvement in the management of existing woodlands, and planting on a large scale, would no doubt change the special kind of *shooting* obtainable, but it would certainly not diminish the amount of *sport*. Rough woodland shooting in France and Germany includes most kinds of game from snipe, wood-cock, wild-duck, wood-pigeons, and capercailzie up to roe-deer, red-deer, and wild boar. Owing to the damage they are apt to do, hares have to be kept well in check. The only form of sport in the United Kingdom which is absolutely incompatible with profitable Forestry is the preservation of rabbits for shooting,—*because rabbits are* **vermin** *so far as plantations are concerned, and timber-crops cannot possibly be grown with profit if rabbits abound.*

Advantages of Shelter from Woodlands.—Apart from any direct monetary profit that might accrue through making large plantations for timber, there are other very important economic advantages that would be at the same time attained in the provision of shelter for agriculture and stock-raising. The way in which plantations may assist Agriculture are well shown in Stephens' *Book of the Farm* (4th edit., 1893, vol. iii. p. 214):—

Shelter from Plantations.—The benefits derivable from plantations in improving land are far more extensive and important than from stone walls. "Previous to the division of the common moor of Methven (in Perthshire) in 1793," says Thomas Bishop, "the late venerable Lord Lynedoch and Lord Methven had each secured their lower slopes of land adjoining the moor with belts of plantation. The year following I entered Lord Methven's service, and in 1798 planted about 60 acres of the higher moor-ground, valued at 2s. per acre, for shelter to 80 or 90 acres set apart for cultivation, and let in three divisions to six individuals. The progress made in improving the land was very slow for the first fifteen years, but thereafter went on rapidly, being aided by the shelter derived from the growth of the plantations; and the whole has now become fair land, bearing annually crops of oats, barley, peas, potatoes, and turnips; and in spring 1838, exactly forty years from the time of putting down the said plantation, I sold 4 acres of Larch and Fir (average growth) standing therein for £220, which, with the value of reserved trees, and average amount per acre of thinnings sold previously, gave a return of £67 per acre."

In addition to the area, above estimated at about 3,342,000 acres, suitable for planting with a view to profit, there is also, however, almost unlimited scope for the formation of shelter-belts for the benefit of arable cultivation and stock-raising. The beneficial effects of the protection that might be provided by woodlands and shelter-belts can hardly be estimated in money, but they would undoubtedly be of much importance in a country where cattle-breeding and sheep-grazing are now the chief form of agriculture.

Grazing in Plantations may also often prove worth some special attention. Owing to our humid climate there is everywhere a strong tendency for the soil to become overrun with a luxuriant and often more or less rank growth of grass and weeds. Even in plantations kept in fairly close canopy grass is usually to be found in Conifer woods after they have reached about twenty years of age. And this is more particularly the case in Larch woods, owing to the light-chequered shade cast by this sparsely foliaged tree. The thin, succulent grass springing up under such Conifer crops is apt to scour cattle before they become accustomed to it; but though not of the first quality, at any rate it attains a bulk as a grass-crop (subsidiary to the timber-crop) far larger in quantity and better in quality than the rough, coarse grazing that is to be found on the adjoining waste land similar to that planted. And when the timber-crop is cleared, there is really first-class grazing obtainable for the next three or four years,—which is just the period that may well elapse before replantation takes place, in order to obviate damage to the new timber-crop from the pine weevil making its breeding-place in the stumps of the felled trees. Thus plantations on a large scale on poor waste land might add in no inconsiderable degree to the grazing area after the plantations attain an age of twenty to twenty-five years, when the admission of sheep and cattle would do no injury to the timber-crop.

Note.—The following comparison of British imports of wood during the twenty years from 1882 to 1902 speaks for itself as regards the present fiscal question now before the country :—

	1882.	1902.
WOOD AND TIMBER—	£	£
Hewn	5,200,000	5,400,000
Sawn	10,800,000	17,100,000
Manufactured	300,000	1,400,000
	16,300,000	23,900,000
PAPER, mostly made of wood-pulp . .	1,200,000	4,500,000
PAPER MATERIALS, mostly wood-pulp .	2,000,000	3,300,000
	3,200,000	7,800,000
Total . .	19,500,000	31,700,000

PART II.

THE BRITISH SYLVA—OUR WOODLAND AND ORNAMENTAL TREES

CHAPTER I.

CONCERNING BROAD-LEAVED TREES.

Only a small proportion of the many trees now to be found cultivated or growing wild throughout the British Isles are really indigenous, though many of those introduced at various times, from the period of the Roman occupation onwards, have become thoroughly acclimatised, and have naturalised themselves as denizens of our woodlands. Owing, doubtless, to our insular position, the really indigenous genera and species are few in number as compared with those found on the continent of Europe. They include the Common and the Sessile Oak, the Beech, the Hornbeam, the Ash, the Scots or Wych Elm, the Sallow, Saugh, or Goat Willow, the Aspen or Trembling Poplar, the Common Birch, the Common Alder, the Rowan or Mountain-Ash, the Common Cherry, the Field Maple, the Scots Pine, and the Yew, together with smaller trees or shrubs like the Hawthorn, the Holly, and the Juniper.

It will thus be seen that many of our most valuable broad-leaved trees, and all of our coniferous trees except the Scots Pine, have been introduced from British colonies or foreign countries at one time or another. But for the practical purposes of Forestry it does not in the least matter whether any of the doubtful kinds of trees were, or were not, originally and truly indigenous to Great Britain. What is of far more importance is that, from long experience, they are known to thrive in our climate, and to have long ago become *denizens* or naturalised trees in Britain, reproducing themselves naturally from seed. In the case of some trees, however, like the English Elm and the Lime, the fact that seed-production is dependent on an unusual degree of summer warmth distinctly points to exotic origin in a warmer clime than ours; but as nature always contrives to effect reproduction, this difficulty about ripening germinable seed is compensated by a vigorous capacity for throwing up strong suckers and stool-shoots.

In this and the following chapter it is proposed to give a description of the useful and ornamental trees in the British Isles. But as it is necessary, in a work dealing specially with Forestry, to differentiate between trees of sylvicultural importance and those possessing merely arboricultural interest, prominence can only be given to the former, the true woodland trees, while all details regarding the latter, the less hardy and the rarer trees suitable only for ornamental planting, are given in smaller type, with a view to economise space.

For convenience the genera have been grouped in their natural families, although otherwise not classified according to any system of botany.

Most of our broad-leaved trees belong to the order of **Amentaceæ** or **Catkin-bearers**, which is divided into five families: 1. *Cupuliferæ* (Oak, Beech, Sweet-Chestnut); 2. *Carpineæ* or *Corylaceæ* (Hornbeam and Hazel); 3. *Plataneæ* (Plane-tree); 4. *Salicaceæ* (Willow and Poplar); and 5. *Betulaceæ* (Birch and Alder).

CUPULIFERÆ Rich.

This family has its fruits surrounded by a cupule or cup formed of aggregated bracts. It is represented in Britain only by two indigenous genera, Oak and Beech, and one acclimatised genus, the Sweet-Chestnut.

Key to Genera.—These three genera are distinguishable as follows:—

I. Female flowers singly or in clusters in the axils of the leaves or in axillary shoots (forming loose spikes), and each surrounded by a cupule, which finally becomes cup-shaped, and surrounds the nut from below. **Oak** . . . . 1. *Quercus.*

II. Female flowers in terminal bunches, or clustered at the base of the male catkins; each covering-bract encloses 2 or 3 of the flowers, which develop into 2 or 3 nuts enclosed within the one cupule, that finally bursts open for the shedding of the seed.

   (*a*) Female flowers in separate terminal bunches; male catkins with a long petiole, and hanging down from the side; cupule covered with short, soft prickles; nuts three-cornered and sharply pointed. **Beech** . . . 2. *Fagus.*

   (*b*) Female flowers clustered at the base of the long spike-like male catkins; cupule covered with long, thin, interwoven prickles; nuts large and plano-convex. **Chestnut** . . . . 3. *Castanea.*

1. THE OAK, *Quercus* (Linnæan System, Monœcia Polyandria).

Generic Character.—*Flowers*, unisexual. *Males*, disposed in long, slender, pendulous catkins, in groups. Each flower consists of 8 or more stamens, and these are attended by 6-8 bracteas, that are coherent at the base, and resemble a 6-8-parted calyx. *Female flowers*, erect on axillary peduncles, a few upon a peduncle. Each flower consists of a pistil, whose ovary and the basal part of whose style are invested with an adnate calyx toothed at the tip. *Style*, short. *Stigma*, 3-lobed. *Fruit*, an acorn; its lower part having an imbricate cup (Loudon, *Trees and Shrubs*, 1875, p. 846).

Apart from doubtful species, A. de Candolle enumerated two hundred and sixty-one species of Oak, chiefly belonging to the northern hemisphere between latitude 30° and 60°. Only six of these need, however, be referred to—viz., the two British kinds, the Common English Oak and the Durmast Oak, as they are preferable to all other sorts for the quality of their timber; the Turkey Oak; the Holm or Evergreen Oak of Southern Europe; and the two American kinds, the Scarlet Oak and the White Oak, as these are hardy and ornamental.

Specific Characters.—These six more important species of Oak are distinguishable as follows:—

I. Bracts of the cupule convex, broad at the base, and then suddenly contracting, grey. Shell of the acorn thin, smooth inside, and without any trace of internal divisions. Seed ripens within one year.

1. Foliage deciduous annually. Leaves with wavy-edged lobes or pinnatipartite.

(1) Leaves with more than 5 pairs of primary side-veins, of an elongated oval form, and with many wavy-lined indentations; glabrous, at any rate when fully developed.

(*a*) Leaves with short petioles, and a broad, crinkled, heart-shaped base. Flowers and acorns arranged sidewards on peduncles. **Common English Oak** . . 1. *Q. pedunculata* Ehrh.

(*b*) Leaves with rather long petioles, and somewhat wedge-shaped at their base. Flowers and acorns sessile, often clustered in racemes. **Durmast Oak** . . . 2. *Q. sessiliflora* Sm.

(2) Leaves with 3-5 pairs of primary side-veins and lobes; the under-surface mostly pubescent. **White Oak** . . . . 3. *Q. alba* L.

2. Foliage persistent (evergreen). Leaves small, leathery, stiff, somewhat shortly oval, and with a greyish pubescent or downy under-surface; edge entire, or with sharp pointed crinkles. **Holm Oak** 4. *Q. Ilex* L.

II. Bracts of the cupule broad at the base, and then narrowing gradually, brown. Shell of the acorn thick, downy inside, and with three false divisions. Seed only ripens in the second year. **Scarlet Oak** . . . . . . 5. *Q. coccinea* L.

III. Bracts of the cupule loose and recurvate. Shell of the acorn thin, and without trace of any internal division. Seed only ripens in second year. Leaves thin, coarse, unequally serrately dentated or pinnatifid. **Turkey Oak** . . 6. *Q. cerris* L.

(1) THE PEDUNCULATE or COMMON ENGLISH OAK,
Quercus pedunculata Ehrh.

SYNONYMS—*Q. Robur* L.; *Q. Robur I. pedunculata* DC.; *Q. pedunculata* Willd.

Distribution.—The Common Oak is a native of nearly all parts of Europe, from Sweden to the Mediterranean; and it is also found in Northern Africa, Asia Minor, and the Caucasian districts. It is the prevailing Oak in all our British woodlands and in the forests of France, but is not more common in Germany than the Sessile Oak. Its northern limit is 58° in Scotland and 63°26′ on the west coast of Norway; but it sinks to 60° in Sweden, and still further as it trends eastwards. Its southern limit for Europe is hardly assignable, as its special characteristics often become interchangeable with those of the Sessile Oak. Its total distribution comprises altogether about 26° of latitude and 66° of longitude, and its finest development is attained in the south-eastern part of Central Europe, more especially in Hungary and Croatia. As compared with the Sessile Oak, the Common Oak is rather a tree of the plains and uplands than of the hills and lower mountain-ranges or of lofty plateaux. In general, more is done throughout England for the artificial distribution of the latter as a timber-tree; but in production of wood and bark on coppice-hags, the former is more profitable, while in highwoods it forms a better bole than the Common Oak.

The spontaneous growth of this species in Central Spain and in Western Russia shows that it can endure great summer heat and great winter cold. But its young foliage is sensitive to late frosts in May, and it is liable to suffer from drought when the summer flush of leaves appears in August, although this is far less the case in our damp climate than throughout the drier regions of Central Europe.

Description.[1]—The Common Oak is a large, massive tree, with spreading top. It naturally tends to throw out large limbs and to become ramifying and flat in the crown. The growth of the tree is, however, very much influenced by soil and situation. On a high, exposed site and a poor soil it is stunted, low-stemmed, and flat-topped; while in a sheltered situation, with a deep strong soil, it assumes a more upright habit. And this again is, of course, modified by given circumstances, as the trees may be drawn up through being close together, or may ramify from standing far apart. In the former case their crowns become comparatively small, whilst the boles are tall and straight; but in the latter case they attain that branching development which renders the Oak so ornamental in landscape scenery. Few estates in any part of the United Kingdom are without fine ornamental Oak-trees, but the largest and most celebrated are in Central and Southern England, the warmest parts of these islands.

There are many Oaks of historical interest and of large dimensions throughout Great Britain and Ireland. The largest specimens recorded are those mentioned in Loudon's *Arboretum et Fruticetum Britannicum*, vol. iii. (1844), pp. 1770 and 1775—viz., the Cowthorpe Oak (Yorkshire), 78 ft. girth; the Merton Oak (Norfolk), 63 ft.; the Hempstead Oak (Essex), 53 ft.; and the Grindstone Oak (Farnham, Surrey), 48 ft. near the ground and 33 ft. at 3 ft. up. The largest Oaks in Scotland are much less than any of these in girth; but they are usually longer in the bole and unpollarded, whereas all the enormously large Oaks in England were pollards, and therefore shorter in stem, though bigger in girth.

Economic Value.[2]—Although Oak timber is not now so much required for shipbuilding as formerly, yet it is still largely used for small

[1] The most marked differences between our two chief kinds of Oak are shown in the following table. But the distinguishing characteristics are not always reliable, as leaves from one and the same tree may sometimes be found to answer both descriptions. The characteristic difference between the short, thick buds of the Common Oak and the longer and more pointed buds of the Durmast Oak is perhaps more constant than those relating to leaves and acorns; while, of course, the habit of growth depends much on soil, situation, and environment. Besides that, as the two species are both indigenous, and are often found growing together, cross-fertilisation may easily account for non-adherence to specific distinctions.

Species.	Buds.	Leaves.	Flowers and fruits.	Habit of growth.
English Oak (*Q. pedunculata*)	Short, thick, blunt	Leaf-stalks short; leaves smooth, and with broad, crinkled, heart-shaped base; side-veins sometimes end in the lobes and sometimes in the indentations	Arranged sidewards on long stalks (see Fig. 1)	Short-stemmed, large-limbed, and branching.
Durmast Oak (*Q. sessiliflora*)	Longer and more pointed	Leaf-stalks rather long; leaves wedge-shaped at base; side-veins always end in the lobes; young leaves generally more or less downy on under-surface, and old leaves usually show traces of pubescence at angles of veins	Sessile; often clustered together in a bunch (see Fig. 2)	More upright and less branching; forms a better bole.

[2] Specific details regarding cultivation of all the woodland trees will be given in Part III. (*Sylviculture*); and regarding insect attacks and fungous diseases, in vol. ii. Part I. (*Protection of Woodlands*); while such data as are available about the yield in timber per acre of Oak, Beech, &c., will be found in vol. ii. Part II. (*Management of Woodlands*).

coasting vessels; and a great quantity of poles and small trees is used in mines.

The fact that crooks and ribs of iron are now used in shipbuilding, in place of Oak-pieces of natural curved or crooked growth, is one of which the importance to Forestry cannot be overlooked. All the Oak plantations made throughout Britain during the greater part of the last 250 years in the State forests (Windsor, New Forest, Alice Holt, Parkhurst, Forest of Dean, &c.), as well as by private landowners, were formed with the express intention of growing wood suited for shipbuilding. Ramification, favoured by free growing-space, was therefore advantageous. But now the best prices are obtainable for long, straight, full-wooded, clean boles, free from knots and branches; and these can only be obtained by growing the trees in woods in such a manner that crown-development is confined merely to the limit necessary for healthy growth, so long as the stems are still capable of being stimulated to greater growth in height.

Fig. 1.

Acorns of the Common Oak (Q. pedunculata).

Oak timber assumes the first place among hardwoods for general technical purposes. It is used for a great variety of purposes in connection with house-building, carpentry, cabinet-making, furniture, gates, posts, &c. In point of general durability its timber (along with that of Larch) surpasses that of any other tree grown in Britain. Unfortunately, however, it is the tree which takes longest to mature.

Large quantities of Oak are still imported from the Baltic and from Austria, but of late years increasing supplies have been obtained from America. The latter is, however, neither so strong nor so durable as English Oak. "Brown Oak" is the trade term for a peculiar kind of wood found mostly in the midland counties, and apparently due to the first stage of decay. It is used for ornamental furniture, and good pieces are worth from 10s. upwards per cubic foot in the rough.

Oak belongs to the very heavy class of woods, having a sp. gr. of over 0·75; its sp. gr. is 1·04 whilst still green, and 0·76 when seasoned in the air. Consequently, if stems have to be floated in order to arrive at a convenient market, some amount of seasoning will have to be provided for in the forest, such as ringing or girdling the stems to a depth of 3 or 4 in. the year before felling them. In Hanover the stems are often *barked* in May and June, and allowed to stand thus for one year before being felled.

As a matter of experience, and despite differences in sp. gr. and other similar tests, the durability of Oak timber in general depends less on the species of tree than on the general quality of the soil upon which it is grown; while the length of the stem depends mainly on the depth and the general quality of the soil.

Soil and Situation.—The rate of growth and the quality of Oak timber of course depend very much upon the nature of the soil and situation. Throughout Britain the best-grown Oak-trees are generally to be found on heavy and deep clay or loamy soil, into which the roots can penetrate well and ramify freely without any check from a change in the character of the subsoil. The Oak will, however, thrive on light and sandy soil, provided this be deep and fresh. But the largest trees and the best quality of timber are usually to be found on deep and heavy argillaceous land. The pedunculate Oak thrives excellently on flat or undulating stretches of deep alluvial soil; and in such cases far less depends on the argillaceous, or the loamy, or the sandy consistency of the soil than on its depth and other generally favourable physical properties. Such rich land, however, is nowadays seldom to be found under timber. For marshy tracts the Common Oak is better suited than the Sessile Oak.

On light loam and sandy soil the Common Oak may attain a girth of 12 to 18 ft. near the base. But it is then generally short of stem, and large-crowned in proportion; while trees of anything like the same girth growing on deep heavy land usually have much longer, cleaner, and more valuable boles. On high-lying and exposed situations the Common Oak will grow, and even become timber of useful size, although the soil be but poor; yet for all such localities, if it be desired to grow Oak at all, the Sessile Oak seems preferable.

Cultivation.—When grown in highwoods, the Oak is usually raised from acorns. Seed-production may begin about the twentieth year in coppice-woods, but does not set in until about the fiftieth to sixtieth year in trees raised in the open from seed, and not until about the seventieth or eightieth year in timber-crops growing in close canopy. The acorns generally ripen in the months of October and November, and germinate during the following spring.[1] So soon as they are ripe, they should be gathered and either sown immediately or else stored carefully, because they are very apt to lose in germinative capacity by being long kept, unless special measures be taken to keep them dry and cool. Only good sound acorns should be collected, and not those that are small or worm-bored. The better way is to sow them at once when gathered, except where voles, squirrels, and other vermin are troublesome, or where late frosts in spring are to be feared.

After sowing, care must be taken that vermin do not devour the acorns. If mice or rats are in the neighbourhood, they will probably attack them in winter; and if so, the vermin must be trapped. And in spring nets may have to be used to cover and protect the rows from pheasants and other birds; or if nets are not obtainable, the rows may be covered somewhat closely with the branches of trees, which will keep back birds while allow-

[1] **Acorn Poisoning.**—In years with exceptionally warm dry spring and summer weather a much larger number of acorns matures than in ordinary years, and then there is danger of young cattle being poisoned by eating largely of the acorns, which they consume with avidity. Considerable mischief was done from this cause during the autumns of 1868, 1870, 1874, and 1893, the greatest sufferers being young cattle under two years of age, whilst milch-cows and cattle over three years old were seldom affected. In deer-parks the acorns form good food for the herds during the winter months.

ing a free circulation of air to the surface of the earth. When the young plants appear above ground about the end of May, these branches should be removed to give the seedlings full, free exposure to light and air. In localities apt to be visited by late frosts, however, caution should be exercised in this respect; and it is best to remove the branches each morning, and replace them towards nightfall, if this can be conveniently arranged for on small areas without incurring prohibitive expense. The seedlings should be kept clear of weeds, as rank growth of herbage greatly endangers their wellbeing.

As a rule, the seedlings should only stand one year in the seed-rows; when left longer, they are apt to become drawn up and weakly. It is preferable to put them out in rows when one-year-old and let them stand for three years in the lines, when they are usually much superior to others that have been left for two years in the seed-bed, and have then stood for other two years in the nursery-rows. They should therefore be transplanted at about 4 in. distance in rows about 1½ to 2 ft. apart, where they may remain till the plants reach the required size. Two years in the rows may be enough if big transplants are not required; but if large, sturdy transplants are wanted, then three and even four years may be needed. On good nursery soil a height of 3 to 3½ ft. may be attained within two to three years after transplanting; but in order to obtain a height of 9 to 12 ft., other four or five years are requisite. Before then, the plants will be standing too thick; but this evil may be remedied by removing every alternate plant, and either planting it out or else setting it in other special transplant-beds, with a reasonable amount of growing-space.

The Oak, during the first year after being transplanted, makes very little progress in growth, but merely establishes its roots in the ground. During the second year it begins to send out new shoots, and from the third year onwards it usually grows vigorously.

Sylvicultural Characteristics.—The Oak is essentially a light-demanding tree requiring a comparatively large growing-space. This natural tendency becomes more marked as it increases in age, after once its main growth in height has been completed. And as, at the same time, high periods of rotation are requisite before the timber acquires its best dimensions and highest marketable value, it therefore follows that, unless it be either grown along with a more densely foliaged tree like the Beech, or be underplanted in order to protect the soil against the deteriorating effects of sun and wind, the land is apt to lose in productivity under the somewhat sparse leaf-canopy of the Oaks alone.

Oak-coppices were formerly one of the most remunerative kinds of Forestry; but now the market for bark has fallen so much, owing to the use of chemical extracts for tanning, that in many places it hardly pays to strip either the underwood or the standard trees in copses. Many of the Oak-woods in Ireland were cleared and converted into highwoods from thirty to fifty years ago by interplanting them thickly with Larch, Scots Pine, Spruce, and Silver Fir. If Oak-coppices could again be made profitable, there are many thousands of acres along railway cuttings and embankments that might thus be utilised, and might provide employment for thousands of the poorer classes, too often unemployed during the spring, when the sap begins to flow and the harvesting of the bark takes place.

Continental Notes.—The modern Continental system of Oak cultivation consists in the formation of Oak crops,—either in pure woods on good, deep, fresh soil, or else in admixture with other species like Beech — or on moist soil, even along with Ash, Elm, Maple, Sycamore, or Alder,—and then afterwards, when the chief growth in height has been attained about the seventieth to eightieth year, in cutting out these other kinds of trees, and either allowing them to shoot from the stool so as to form a natural undergrowth, or else sowing or planting some soil-protecting species of underwood like Beech or Hornbeam, which are there always saleable as fuel. During the whole of the earlier period of its existence, it is of course essential that the Oak, which is to form the ultimate crop, must be constantly protected during all the operations of weeding, cleaning, and thinning, so as to remain growing in advance of any competitors for light and air. The freer enjoyment of light and air which is thereafter accorded to the standard Oaks either by thinnings or by partial clearances, conducted every ten to twenty years for the express purpose of stimulating their increment in girth, is accompanied, as experience in the State forests of Germany has abundantly shown, by rapid and material improvement both as regards the quantity and the quality of the timber produced. This method attains, in an improved form, not only the practical advantages as to light and air formerly obtained by growing the Oak as standards over coppice in the old form of *copse*, but also combines therewith special advantages of its own in the formation of the longest possible bole, having the maximum of girth at the top end as compared with that of the butt.

After being stimulated in rate of growth from time to time by partial clearances, the Oak then usually attains its full maturity about the 140th to 160th year, when it is at least equal in dimensions to stems of considerably greater age that are merely treated by the ordinary method of thinning.

When such Oak-forests come to be regenerated, this can generally be effected easily by natural means,—for the soil is usually of good quality, else it would be more profitable to grow mixed coniferous crops than Oak. A little soil-preparation, either in strips or patches, will generally be sufficient to produce a fair crop of young seedlings, which can be supplemented, if necessary, by dibbling acorns more or less regularly over the area at a comparatively small cost. When once the seedlings have made their appearance, the standard trees require to be cleared away soon; for the light-demanding Oak suffers even under the partial shade of the parent trees. Of course, on good fresh soil the risk of damage by overshadowing is not so great as where the soil is poor and dry, because in the latter case the night dews contribute greatly towards the wellbeing of the seedlings. As the standards are being cleared, blanks may be filled either by planting, or by sowing acorns, or else by introducing other kinds of trees, of which, on all soils that are not of a distinctly good class, and more especially if they have a tendency to be deficient in moisture, the Beech is most to be recommended. On better and moister classes of soil a larger choice of species is open, most of which hold out promises of profit exceeding any that may be anticipated for the Beech. But wherever there seems any danger of the soil deteriorating under the lighter shade of the Oak, Ash, Maple, Sycamore, &c., an admixture of some shade-bearing and soil-improving species is advisable in order to safeguard the land against exhaustion and loss in productive capacity, *for the maintenance of the continuous productivity of the soil is one of the fundamental principles in Continental Sylviculture.* With regard to this Continental method of growing Oak timber, it must of course be recollected that Beech is there everywhere readily disposable at good prices as fuel, which is certainly not the case in Great Britain and Ireland; hence a method that is excellent both in theory and in practice in France and Germany may be quite unsuited for the circumstances of private woodlands in the British Isles.

Throughout the whole of the Rhine district, and in the neighbouring parts of France, Belgium, and Holland, **Oak coppice-woods** occur very extensively, and yield high returns. They are usually worked with a rotation of sixteen years; but this varies locally from about twelve to eighteen years, according to the nature of the soil and situation, and the age at which the young bark begins to lose its smoothness and become fissured,—for the quantity of tannin contained in it diminishes when the cortex becomes rough and rugged. For the satisfactory growth of Oak-bark coppices, a good soil, though not necessarily deep, and a warm southern exposure are needed. When Oak coppice-woods are being formed for the first time, planting is greatly preferred to sowing, as more quickly attaining the object in view, and as being safer on the whole, although more costly. Sometimes the seedlings are put in whole, as in the ordinary method of planting, and afterwards cut back close to the ground when they have established themselves firmly in the soil; but at other times the stems are lopped off with a clean cut against a wooden block, and only the roots are planted in the ground. The chief points to be kept in view in such coppice-woods are to see that cleaning and weeding operations are carefully performed, so that the Oaks remain in undisturbed possession of the soil. The reproduction of the annual hags takes place spontaneously by vigorous shoots from the stool, which often form root-systems for themselves independently of the parent stool, if the poles be felled low down and as nearly as possible flush with the ground.

The Sessile Oak throws out straighter and somewhat more vigorous shoots than the Common Oak, and yields more wood and bark. The quality of the bark of the former is also rather better than that of the latter, more especially when the crop is grown on elevated hill-slopes.

(2) THE SESSILE or DURMAST OAK, *Quercus sessiliflora* Sm.

SYNONYMS—*Q. Robur* L.; *Q. Robur II. sessiliflora* DC.; *Q. sessilis* Ehrh.; *Q. sessiliflora* Sal.

Distribution.—The Durmast Oak is dispersed over nearly the same range of countries as the Common Oak, and they are generally found growing together from Sweden southwards to the Mediterranean. It is common all over Great Britain and Ireland; and in France and Germany it often forms very extensive forests, along with the Common Oak, Beech, and other trees. Its distribution is, however, somewhat more restricted than that of the Common Oak towards the north and the east. Its northern limit is below 59° in Scotland, below 60°11′ on the west coast of Norway, and below 58°30′ in Sweden, whence it trends east across Central Russia to about 54° towards the southern portion of the Ural Mountains. From there its eastern limit passes across the Crimea to Asia Minor, where its southern limit begins about the 40th degree of latitude. It can, however, at the same time ascend vertically considerably beyond the elevation attainable by the Common Oak. The explanation of this seeming anomaly must be that whilst the Sessile Oak can bear less winter cold than the Common Oak, yet it can thrive with less of summer warmth (Willkomm).

Fig. 2.

Acorns of the Sessile Oak (Q. sessiliflora).

Wherever there are extensive natural forests of Oak, both species will usually be found growing together, although on lowland tracts the Common Oak will greatly outnumber the Durmast. But as the woodlands stretch to the higher uplands and the hilly tracts, so will the trees of the latter species gradually increase in number. From natural spontaneity of this sort useful hints may be gained by the sylviculturist, and as a rule it is best chiefly to cultivate that species which seems to form the majority of the old crop. Throughout Central Germany in old coppice-woods, and in Oak-forests that have been reproduced naturally, the Sessile Oak is more numerous than the pedunculate, which would point to its probably being able to bear shade somewhat better than the Common Oak; but in younger woods raised artificially by sowing or planting, a preference seems to have been given to the latter species, probably on account of the somewhat larger size of the acorns (Burckhardt, *Säen und Pflanzen*, 1893, p. 14).

Description.—The two species grow nearly alike, so far as attainable dimensions are concerned; but *Q. sessiliflora* generally assumes a more open and upright habit than *Q. pedunculata* (see footnote 1 to p. 108). Trees of the former kind have a cleaner bole and in all respects a lighter aspect than those of the latter, whose limbs are usually more knee-bent and gnarled. The Sessile Oak is usually about ten to fourteen days later in breaking into leaf than the Common Oak.

Economic Value.—The timber of the Sessile Oak, although somewhat softer and easier to work, is practically just as durable as that of the Common Oak; and the wood of the one kind fetches the same price as that of the other, for buyers do not differentiate between the two species. When young, the timber of the Durmast is of a more open texture than that of the Common Oak of the same age; but as it becomes older, it becomes nearly as compact and solid. Its sp. gr. is just a very little lower than that of the wood of the

Common Oak, being 1·01 when green and 0·74 when seasoned. Seasoning to some extent, either by means of girdling, or barking, or of letting the logs lie in the forest, is therefore required before they can be floated to convenient sale-depots.

Soil and Situation.—The remarks made with reference to the Common Oak apply generally to the Sessile Oak, except that the latter is more frequent on hilly land, whilst the Common Oak is the chief species on low-lying tracts. In order to thrive in highwoods, both demand a fair depth of soil, and more especially a considerable amount of freshness, or even moistness, in it. It may be remarked here, however, that the Durmast Oak makes a much better hedgerow tree than the Common Oak, because it has a more upright habit of growth, and is more easily kept from spreading its branches and injuring the field-crops by the heavier shade thus cast.

Cultivation is as described with reference to the Common Oak.

(3) THE WHITE OAK, *Quercus alba* L.

Distribution.—The White Oak is plentiful in Canada, and in the Northern States of America generally, especially in western Pennsylvania and Virginia, where it grows to large dimensions on good land with rich, light, dry soil. It is plentiful in the upper valley of the Madawaska river, tributary to the Ottawa in Canada West, where it is always to be found on rich land, and but seldom on poor soil. It was introduced into Britain in 1724.

Description.—This tree derives its name from the white colour of its bark, which distinguishes it from all other Oaks. It much resembles the Sessile Oak; but on good land the leaves are larger, and the hollows along the edges of the leaf are deeper. In its native woods it attains a height of 75 to 90 ft. In the Madawaska valley this tree may often be seen with 60 to 70 ft. of stem clear of branches, and having a mean diameter of about 4 ft. Trees measuring about 110 ft. high, when cut down, were found to contain upwards of 500 cubic ft. of timber, and to be upwards of 400 years old. In many parts of Central and Southern England good specimens of this tree are to be found; and even in Scotland it sometimes attains dimensions equal to British Oaks of the same age.

Economic Value.—White Oak is one of the most valuable Oak-trees in America, and is largely used in housebuilding and for most purposes, from shipbuilding to handle-making. It is largely imported from Canada under the name of "American Oak."

Soil and Situation.—To have a fair chance of doing well in the British Isles, it requires a rich, deep, light loam and a sheltered position. It will not thrive on poor soil or in an exposed situation. It is perfectly hardy, however, and will grow on most soils and sites neither too poor nor too much exposed; but to attain any size as timber it must have good soil and a warm site, giving it a fair chance of overcoming the unfavourable conditions of our climate.

Cultivation.—Like our own two Oaks, the White Oak ripens its acorns during the autumn of the same year in which it flowers. It can easily be raised from seed always obtainable from America; but as it is not a prolific seed-producer, the acorns are rather high-priced. As soon as obtained, the seed should be sown in the same way as described with respect to the Common Oak. And later on it should also be dealt with in very much the same way as the British Oaks. But as a tree of our woodlands, it is never likely to compete with our two native species.

(4) HOLM or HOLLY OAK, or EVERGREEN OAK, *Quercus Ilex* L.

Distribution.—The Holm Oak is a native of the Mediterranean districts, of Southern France, Spain, and Italy. Its northern limit trends from about Lake Garda across the northern part of the Adriatic to Trieste, where it is usually found only as a shrub on the mountain-sides; for it does not attain the dimensions of a tree farther north than the island of Quarnero.

It does not naturally grow in masses, but is for the most part scattered here and there among other trees. It is frequently to be found of true forest growth among the woodlands throughout Spain and Portugal, on the islands throughout the western half of the Mediterranean Sea, on the hills in Sicily, and all along the coast. It ascends Mount Etna as high as 3200 ft. above the level of the sea, and to within about 800 ft. of the elevation at which *Q. cerris* is found, and it has been found at over 4000 ft. on some of the other islands. As might be expected from this, it is a hardy tree in our somewhat similar, but colder, damp insular climate; for in Britain it is found to be remarkably hardy, and to grow well close to the sea-shore, where no other European Oaks thrive.

Description.—In favourable situations in its native countries this tree attains a height of 35 to 60 ft.; but in the British Isles it does not generally attain the dimensions of a timber-tree. Yet it has one ornamental advantage in that, when standing alone, it becomes thickly clothed from the ground to the top with a dense mass of branches and of leaves, which produce a handsome effect. But when confined among other trees, it forms a clean stem of fair height. The leaves of this tree vary much in shape and size, thus giving rise to varieties that have received special names—such as *latifolia*, broad-leaved; *crispa*, curled-leaved; *oblonga*, long-leaved, &c., &c. The leaves are dark green in colour; and from their being convex above, and quite smooth, they give a rich, full, shining appearance to the tree as a whole. As also in the case of the Common Holly, the serrated spines or leaf-teeth are confined to the lower branches, while the foliage of the upper branches have an entire edge. And in both cases the spinosity of the lower leaves is increased by pruning or by the grazing of animals. In favourable parts of Britain, as in the warmer southern tracts of England, trees raised from seed grow very rapidly, often attaining a height of 20 ft. in twelve years; but in Scotland they grow much more slowly, seldom attaining over 10 ft. in as many years. This tree is said to live to a great age, and to continue in a healthy condition for several centuries.

Economic Value.—The matured heartwood of the Holm Oak has a dark-brown colour and a very close grain; it is very heavy, and so hard as to be difficult to work. In Britain the tree is grown more for ornament than as timber, although it takes a fine polish and is suitable for furniture. On the Continent it is much used for furniture-making and for charcoal.

Soil and Situation.—The Holm Oak grows best in a deep, light, dry soil of a limy, marly, or sandy description. It will not thrive unless the soil is deep, free, and open; nor will it do well if the subsoil be at all wet. It grows better on a sandy soil than on clay or loam. It should be planted in rather a warm, sunny, low-lying, and sheltered part, so as to secure conditions approximating as nearly as is possible in our climate to those obtaining in its own habitat.

Cultivation.—Seed-production begins very early,—from about the twelfth or fifteenth year onwards. It flowers in April or May, and the acorns ripen during the October of the same year. The fruits formed in Britain, even in warm seasons, cannot be relied on to have good germinative capacity; hence the tree is usually raised from acorns procured from abroad, while casual varieties are reproduced by grafting or layers.

As the plants run very much to tap-roots, and are difficult to transplant safely, nurserymen generally grow them in pots, from which they can at any time be easily and safely transplanted. No tree is more difficult to transplant than the

Holm Oak ; for the roots go so deep into the subsoil, and are so badly supplied with fibres, that transplanting seldom succeeds without careful previous preparation. And of course anything that tends to prevent displacement or disturbance of the mother-earth around the root-system at the same time helps to make the transplanting successful.

There is a very fine avenue of Holm Oak at Courtown House, Co. Wexford, Ireland ; and close to the house is the largest specimen I have ever seen, though unfortunately the short stem is cleft and damaged.

(5) THE SCARLET OAK, *Quercus coccinea* Willd.

Distribution.—This North American Oak has been long cultivated as an ornamental tree in this country, and is well known from its beautiful shining green leaves, which in early autumn become a brilliant scarlet. Its range extends from Florida and Texas to Missouri, Massachusetts, and Nova Scotia. It is abundant in New Jersey, where it forms a glow of scarlet in the autumn, giving an indescribable character to the foliage of the woods. It is also found in Canada along the shores of Lake Ontario, but it is not nearly so common there as in the Northern States of the Union. It was introduced into Britain in 1691.

Description. — The Scarlet Oak grows to a large size in America. Under favourable circumstances it is 80 to 90 ft. high, with a stem from 2½ to 4 ft. in diameter. The tree is of an open habit of growth. The bark is generally dark and thick. The wood is coarse and open in texture. The leaves are generally large, and vary much in shape ; sometimes they are nearly entire, but in other cases ragged. The latter form of the leaf is general when the trees are old, while the former shape prevails in the foliage of young trees. It is perfectly hardy in Britain, and on favourable situations forms stems of considerable dimensions.

The Scarlet Oak is very apt to be mistaken for another closely allied North American species, the **Red Oak** (*Q. rubra* L.),[1] the leaves of which also turn a bright red in autumn. The former may, however, be recognised from the latter by its deeply indented pinnatipartite leaves, whereas those of the latter are broad, with shallow sinuosities, and with pointed and coarsely toothed lobes. The latter is very rapid of growth, coppices well, retains its bark smooth for a long time, and is rich in tannin.

Economic Value.—The wood of the Scarlet Oak is of little value. It is so porous and open of texture that even in America it is chiefly used for making staves for dry-goods barrels. It does not even make a fair firewood. It is therefore only an ornamental tree ; but none can well be more effective in autumn, when its foliage takes on the scarlet hue.

Soil and Situation.—In Britain it thrives on a rather light dry soil, but not on heavy cold clay. In America it grows on a great variety of soils—even on the *débris* of rocks it may be found as a tree of fair size ; but the best specimens are generally found on deep, light, dry soils having warm and sheltered situations.

Cultivation.—Like the *Q. cerris*, the fruit of the Scarlet Oak only ripens in the second autumn after the flowering. The acorns of this species are imported from America, and raised in the same way as those of the British Oak. As stated above, this cannot be said to be a tree worthy of cultivation for the sake of its timber ; still, as an ornamental tree, there is not any other that can even compare with it—except perhaps its own near relative the Red Oak—in the beauty of its foliage, and for this reason it may be recommended to the notice of arboriculturists.

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[1] In Germany the Red Oak has been found to be more accommodating as to soil and situation than the Common Oak, but not to produce such good timber. It is also hardier against late frosts.

(6) THE TURKEY or MOSS-CUPPED OAK, *Quercus cerris* L.

SYNONYMS—*Q. austriaca* Willd.; *Q. crinata* Lam.

Distribution.—The Moss-cupped or Bitter Oak is a native of South-eastern and Southern Europe, of Spain, France, Italy, lower Austria, and as far east as Turkey. Its northern limit of spontaneous growth has not been accurately determined, but probably extends from lower Austria to Moravia, and thence to the north-west part of the Jura in France (Willkomm). It was introduced into Britain in 1735.

Description.—Like our British Oaks, this is a deciduous tree, growing to a height varying from 50 to 100 ft. according to soil and situation. It grows well in Britain, and is often of much more rapid growth than either of our two species. Standing singly in a park, it forms a fine spreading tree, with somewhat pendulous branches; and it therefore offers an agreeable change among other trees of more upright habit of growth. But it does not resist storms or high winds well, and is very apt to become injured and broken in exposed situations. In England it is not only common in parks, but also in many woods and plantations, where it attains a considerable size within forty years. In height and general dimensions it far surpasses the British Oaks of that age growing on the same land along with it; but notwithstanding this, it can never rival them for growing in woodlands worked on business principles.

The Turkey Oak breaks into leaf, along with the Common Oak, about the beginning of May, and sheds its foliage towards the end of October. Its growth in height is completed much sooner than is the case with our two indigenous species, and as regards longevity it takes a much lower position than they occupy. It possesses a strong capacity for reproducing itself by means of shoots from the stool; but as the bark on these shoots soon begins to get rough and fissured, it is not so suitable for coppice-growth as the Common and the Sessile Oak.

Economic Value. — The timber yielded by it in Central and Southern Europe has a sp. gr. of 1·10 when green and 0·85 when seasoned, so that it is considerably heavier than that of either of our two British Oaks. Indeed, with the exception of the Holm Oak, it is the heaviest of all native European woods, being on the average even heavier than the Yew. The wood of the Turkey Oak is nothing like so durable as Common Oak when exposed to damp and weather. It is suitable for furniture, but not so well adapted for general indoor work, as it is apt to be attacked by insects. It is fine-grained and well flowered, takes a good polish, and is therefore suitable for cabinetmaking; but old trees have often heart-shake.

Soil and Situation.—The *Q. cerris* thrives in most dry loamy soils, but does best on deep and dry land, and in warm sheltered positions. It never does well on bleak exposures with poor soil. In its own home it grows best on deep, stiff, argillaceous loams and clayey limes with sunny exposures; and though also not infrequently found on sandy soil or rocky ground, yet the former situations are its true habitat.

Cultivation.—The Turkey Oak attains the power of reproducing itself from seed at an earlier age than either of our indigenous species, but does not seed so regularly. The moss-cupped acorns, however, do not ripen until the second autumn after the flowering. During the first autumn the young acorn is about the size of a pea, and is enclosed completely by the cup or cupule. In average years its acorns ripen fairly well in Britain, and especially in the warmer midland and southern counties of England; and plants can easily be raised from them in the same way as with our two British Oaks. Such seedlings are very apt to *sport* or run into varieties differing from the parent tree either in leaf, seed-calyx, or general habit of growth ; and any such variety can generally be cultivated by grafting either on a stock of this or of a British Oak. In fact, the Turkey Oak is principally propagated by grafting, as nurserymen and arboriculturists find they can produce the exact variety wanted. There are many of these grafts now in cultivation.

2. THE BEECH, *Fagus* (LINNÆAN SYSTEM, MONŒCIA POLYANDRIA).

Generic Character.—*Male Flowers* in stalked drooping heads or capitate catkins, 3 or 4 in each, attended by minute deciduous bracteas. Each flower consists of a 5-6-cleft bell-shaped calyx, and 8-12 stamens, that arise from the bottom of the calyx, and extend beyond its mouth. *Female flowers* borne 2-6 together, within a pitcher-shaped indistinctly 4-lobed involucre, constituted of numerous unequal bracteal scales, and interior scales, grown together. Each flower consists of a calyx, lengthened into a laciniate limb, and investing the ovary. *Fruit*, nuts (Loudon).

Ten species of the genus *Fagus* are known, but only one of these, the Common Beech, is indigenous to Europe. Three are natives of South America, one of North America, one of Japan, and four of New Zealand (Willkomm). Of these ten species only two are grown here, the Common Beech of our woods (*F. sylvatica* L.) and the American Beech (*F. ferruginea* Ait.) The latter is easily distinguishable by its leaves being larger and rather like those of the Sweet-Chestnut, from which again they differ essentially by being pubescent or downy on the under surface. Several varieties of the former are also cultivated in our nurseries, of which the Copper Beech (*F. sylvatica atropurpurea*) is best known, and most frequently to be met with in parks and ornamental plantations. Reference need only be made here to the Common Beech, as it is the only species cultivated as a timber-tree in this country.

THE BEECH (*Fagus sylvatica* L.)

Specific Character.—*Leaves* ovate, glabrous, obsoletely dentate ; ciliate on their margins (Loudon), but only when young.

Distribution.—The Beech is indigenous to most of the temperate parts of Europe, from Norway to the Mediterranean, and from England to the Caucasian districts and northern Persia. It is plentiful in the southern parts of Russia. It is not indigenous to Scotland or Ireland, but was introduced about the beginning of the eighteenth century. Its northern limit of spontaneous growth now lies in Scotland between latitude 56° and 57°, whence it extends to 60°31′ on the west coast of Norway and trends south-eastwards. Its southern limit extends from Asia Minor, through Greece, and along the Mediterranean coast to France and Spain. It is still to be found forming natural woodlands on the range of chalk-hills forming the backbone of Central and Southern England. It must have been the chief tree in the ancient woods in these parts, and it is still the most characteristic tree on the Chiltern hills and the ranges extending over Bucks, Berks, Dorset, Hants, and Wilts. Its finest growth in woodland masses in England is in Bucks. Even in Scotland Beech thrives in all the southern and central parts, and also attains good dimensions in some of the milder of the districts farther north.

Description.—Except as regards late frosts in spring, the Beech is one of our hardiest trees. Even when growing in exposed situations and on poor, thin, gravelly soil, no tree appears to stand the storms so well. In many high-lying parts of Scotland, where even the Scots Pine fails upon thin soil, the Beech can often grow and make good shelter in the vicinity of the sea-shore. It is consequently a good tree for planting along the sea-coast as a protection for other more valuable forest-trees. It can only, however, be expected to attain large dimensions if planted in a sheltered place.

Besides being hardy, the Beech is also highly ornamental, and it very often attains large dimensions. When grown in close masses, it forms a tall, clean stem; but in the open, although reaching a good height, it throws out many branches spreading almost horizontally, and drooping down to the very ground. When in full leaf the tree has, owing to the leaves being extended in the same plane as the shoots, and notwithstanding the actual density of the foliage, a somewhat light and airy appearance, which contrasts well with the rather heavy and sombre aspect of the Sycamore or the Horse-Chestnut. Although under favourable circumstances it may attain an age of about 300 years, in point of longevity the Beech ranks below Oak, Sweet-Chestnut, and Elm. It is easily known from any other forest-tree by its smooth grey bark and light-green, silky, ovate leaves. Whilst still young and soft, these are ciliated along their edge, although when fully developed the foliage loses all trace of this delicate fringe. Young trees generally retain their foliage during winter; but after about fifteen to twenty years of age, the leaves fall like those of any other deciduous tree. If the Beech be kept closely clipped as a hedge, however, it retains its dead russet leaves in winter, and this makes it one of the best of all the broad-leaved plants for a hedge where shelter or privacy is the object, for it can easily be grown to a height of 10 or 12 ft.

Fig. 3.

Young shoot of the Beech. a. Simple leaf-bud; *b.* Male flowering-bud; *c.* Female flowering-buds.

The young shoots (see Fig. 3) are numerous upon the larger branches, are rather slender in appearance, and are somewhat brittle. The Beech breaks into leaf in April or May, about fourteen days in advance of the Common Oak, and flowers at the same time, the fruits or "Beech-nuts" ripening in the following autumn. It sheds its foliage about the end of October or in November; and until the fall of the leaf, it is one of the handsomest trees in the woods in autumn, after assuming its warm russet hue.

The Beech attains a large size on suitable soil. In the chalk districts of England trees are to be found upwards of 110 ft. in height, and from 4 to 6 ft. in diameter at 5 ft. from the ground. In many places in Scotland fine specimens measure from 80 to 100 ft. in height, and have stems of proportionate diameter. In Ireland, one measuring 21 ft. 1 in. at 5 ft. up is to be found at Rossanagh Park (Ashford, Co. Wicklow).

Economic Value.—Beech timber has now no high general value, though it was formerly in much greater demand and better repute. The anonymous author of *Planting and Ornamental Gardening: a Practical Treatise* (London, 1785, p. 167), remarks that—

> In point of actual *use*, the Beech follows next to the Oak and the Ash; it is almost as necessary to the cabinetmakers and turners (especially about the metropolis) as the Oak to the shipbuilder or the Ash to the plough- and cart-wright.

As the wood is brittle and short-grained, it is not well suited for purposes where strength and durability are required. But at the same time, it is the most profitable tree that can be grown as a woodland crop on the chalk-hills of Southern England, where the chairmaking industry of High Wycombe and that neighbourhood is dependent for part of its raw material on the local Beech-woods. Unless utilised in dry situations or entirely under water, it is not durable. If exposed to alternation of moisture and warmth, its wood soon becomes attacked by insects and by saprophytic fungi; and even if it be kept dry, as in the roofing in a house, it lasts only a short time in comparison with many other sorts of timber. At one time it was in demand for machinery, particularly by mill-wrights, but is now very little used thus. Its chief uses are for chairmaking, framing for household furniture, panels for carriages, carpenters' planes, wooden bowls, granary shovels, boot-lasts, small articles in turnery, and for making charcoal for colour-manufacturers. On the Continent it is also used for carpentry work on stairs, parquet-flooring, railway sleepers, wood-pavement, bent-wood furniture (Austria), carts, and many parts of agricultural implements. It is very extensively used as fuel for domestic heating, as its heating-power surpasses that of most other woods. It has a specific gravity of 0·90 when green and 0·71 when seasoned; hence if floating operations have to be carried out, some little time of seasoning is requisite to obviate risk of its getting water-logged and sinking.

Soil and Situation.—The Beech will thrive on most dry, or merely fresh, light soils occasionally moistened by rainfall; and it does well on those of a sandy nature, more especially if they rest on a loamy or marly subsoil. But it attains its best growth on soil of a more or less limy description, even when this is so argillaceous as to be somewhat heavy and stiff. The best and largest crops are usually to be found on a dry and rather light description of soil, having a considerable proportion of lime or chalk; and it is the best natural fertiliser of poor chalk and limestone soil. In our damp insular climate, where transpiration is less rapid than in the drier Continental climate, it does not succeed so well on land at all of a wet character either as to soil or subsoil. Shallow land or very rainy tracts are not suited to it. But whereas, from an ornamental point of view, the Beech is of a very accommodating nature with regard to soil, this can hardly be said of it from the sylvicultural point of view. In order to grow it profitably in dense masses kept in close canopy, so as to produce clean timber and improve the soil with a rich fall of leaves annually, a decidedly better quality of soil is requisite than will sustain most coniferous crops; because, although not making anything like the same demands annually on the soil for mineral nutrients as the Ash, Italian Poplar, Elm, Lime, Horse-Chestnut, Maple, and

Sycamore, nor even quite so much as Aspen, Willow, and Oak, yet it is by no means so easily satisfied as Birch and Alder, or as Larch, Pine, and Spruce (see Part III., *Sylviculture*, chap. i.)

Throughout Central and Western Europe the Beech is to be found forming large forests in the lower hilly tracts beneath the various regions devoted to Silver Fir, Spruce, Scots Pine, and Larch. There it thrives better on the cooler northern and eastern aspects than on the warmer southern and western exposures. For, in the usually dry Continental climate, *freshness* in the soil is necessary to its best development, whereas in our more humid insular climate a dry soil is not prejudicial to its development so long as occasional showers may be relied on.

Any long-continued excess of soil-moisture is inimical to its thriving. Hence moist flat tracts on which the pedunculate Oak grows luxuriantly are not well suited for the Beech; and, fortunately enough, the Beech is not required there, as the soil may usually be more advantageously utilised for mixed crops of Oak, Elm, Ash, Maple, and Sycamore.

In localities exposed to frost, young seedling growth of Beech is apt to suffer a good deal unless protected either by parent standards or by nurses. Where, however, the soil is dry, the parent trees must be removed early, in order not to intercept the formation of beneficial dew at night.

Cultivation.—Although endowed with a fair reproductive capacity of shooting from the stool, the Beech is usually propagated only from seed, gathered when the nuts fall from the trees in October and November. Some sow the nuts in beds immediately after they are gathered, but this exposes them to the attacks of mice and other vermin throughout the winter. It is better to store the seed over winter, and sow in spring. As coppice or underwood, Beech is only well suited for limy soil, and even then should only be worked with a rotation not lower than from twenty to thirty years. But for most of our woodlands having a fresh soil and a sunny situation, coppices or underwoods of Ash or Hazel—and especially Chestnut, unless on limy soil—offer a fairer chance of profit than Beech.

Continental Method of cultivating Beech.—In France and Germany the Beech is usually grown from seed, or regenerated from parent standards, as its power of shooting from the stool is not so great as in many other species of trees. When grown along with Oak, it is usually cut out at about seventy to eighty years of age, being then reproduced from mast as an underwood for the protection of the soil until the Oak standards attain maturity about seventy or eighty years later. When Ash, Elm, Maple, and Sycamore are mixed with Beech, they are generally utilised a few years before the regeneration of the Beech takes place: their removal stimulates seed-production in the Beech, and makes the natural regeneration of the latter easier than it otherwise might be, besides also in some cases obviating the necessity for artificial formation of underwood by means of sowing or planting.

As in all such mixed woods the Beech is introduced mainly with a view to the better production of the more valuable species of trees than can be attained if they are grown without its aid, it of course follows that throughout the whole life-period of the timber-crop these species must be favoured during all thinning operations. It is best to regenerate the Beech first of all, so as to form a matrix, and then to plant the different kinds of trees in small patches here and there, wherever the soil is well suited to their natural requirements. By using stout plants, these more valuable species secure several years' growth in advance of the Beech; and during the natural process of development of the woods towards maturity, the axe must be frequently brought into play to protect these more valuable trees whenever they seem likely to be interfered with by the Beech.

Sylvicultural Importance of the Beech.—The true importance of the Beech in woodlands can neither be immediately noted nor accurately estimated in Britain. In the mountainous regions of Scotland the summer is too short, and the total amount of warmth from May till October is too small, to enable this tree to be of any sylvicultural importance. In Central and Southern England the small scattered tracts maintained under Beech-woods are seldom extensive enough to permit of the Continental system of treatment, by which Beech is made to yield excellent returns (where the market for Beech is, however, far better and more constant than here).

All Continental foresters agree as to the importance of the Beech in preserving the productivity of the soil when once the more light-demanding trees begin to show signs of broadening their crowns and lessening the density of their leaf-canopy after having completed their main growth in height. Ney (*Waldbau*, 1885, p. 93) well expresses this general consensus of opinion in the following words:—

> Grown in pure crops, the Beech merely belongs to the more valuable class of trees through its natural power of protecting the soil; but in mixed woods this capacity for overshadowing the soil, and for improving it by a rich fall of leaves, becomes of very great importance. A suitable admixture of Beech enables all species of forest-trees to thrive much more vigorously than when they are grown in pure woods. It conserves the productive capacity of the soil better than any other kind of tree, and may therefore well be termed *the mother of the woods.*

This fact is explainable by the great capacity of its root-system for assisting in the circulation of air throughout the soil, by its undeniable **shade-bearing capacity**, and by its leaves, easily decomposable and rich in potash, yielding the very best quality of *humus* or leaf-mould; while botanical and chemical specialists also consider the beneficial effect partly due to the symbiotic action of root-fungi (*Mycorhiza*).

This indirect value of the Beech seems in Britain to have long remained unrecognised; and even now it receives less practical recognition than it deserves. Had these sylvicultural characteristics of the Beech been known and utilised as they might have been, the State forests in Hampshire and Gloucestershire, &c., would now be far more valuable than they are.

3. THE SWEET-CHESTNUT, *Castanea*
(Linnæan System, Monœcia Polyandria).

Generic Character.—*Male flowers*, each consisting of a 6-parted calyx, and 10-15 stamens, affixed to its bottom, and extended beyond its mouth. Flowers sessile, and disposed in groups along axillary stalks ; each group consists of many flowers, and is involucrated by a bractea and a bracteole. *Female flowers*, consisting each of an ovary tapering to the tip, clothed with a calyx, and crowned by its 6-7-8-cleft limb, and bearing as many styles, and having as many cells, with two pendulous ovules in each. The flowers are disposed 2-3 or more together, within a bell-shaped and externally bristly involucre. *Fruit*, 2-3 nuts, included in a 4-valved involucre (Loudon).

There are four known species of Chestnut, two of which belong to North America, one to Japan, and one to Europe. Of these only two species are named in our catalogues of plants—viz., the Common Chestnut (*C. vulgaris*) of Europe, and the Dwarf Chestnut (*C. pumila*), a shrub found in the Southern States of North America. The former, to which alone particular reference need here be made, is much cultivated in many varieties on the continent of Europe, and especially in Italy and France, for the sake of its fruit.

THE SWEET or SPANISH CHESTNUT, *Castanea vulgaris* Lam.

Synonyms—*Fagus Castanea* L.; *C. vesca* Gaert.; *C. sativa* Mill.

Specific Character. — *Leaves* oblong - lanceolate, acuminate, mucronately serrate ; glabrous on each side (Loudon).

Distribution.—According to Pliny, the Sweet-Chestnut was originally introduced into Europe from Western Asia about 504 B.C. But so far as anything authentic is known, it appears to be indigenous to all Southern Europe from Spain and Portugal, where it forms extensive forests, eastwards along the Mediterranean to the Caucasus. In the warmer regions throughout lower Austria, Croatia, and Dalmatia it also forms large timber-forests ; and it is likewise of true forest growth along the Italian and French Riviera. It is found both in Eastern and Western Asia, in Northern Africa, and in the North American woods.

Description.—In favourable situations the Chestnut often attains larger dimensions than the Oak. In a park or lawn it is a highly ornamental tree, very much resembling the Oak in general appearance, and, like it, reaches a great age. Here it can attain 70 ft. in height and 4 to 6 ft. in diameter; but there are many specimens of much greater dimensions. The most celebrated specimen of this tree ever known in Britain is

> The venerable Chestnut-tree growing in the garden at Tortworth-house [Earl of Ducie, Gloucester] mentioned by Evelyn, in his *Sylva*, as being known to be 500 years old in the reign of King John. The tree, even now, makes a good appearance in branches and foliage, is in high proof, and, in 1844, bore a considerable quantity of fruit. It was measured in 1791, and found to be 44 ft. and 4 in. in circumference (Rudge's *General View of the Agriculture of the County of Gloucester*, 1813, p. 241).

But the accuracy of these figures is disputed in Marshall's *Planting and Rural Ornament*, 1796, vol. ii. p. 127.

The largest seen by me is in Ireland, on Col. Tighe's estate of Rossanagh Park (Ashford, Co. Wicklow). It girths 33 ft. at 3 ft. up, and 28 ft. 3 in. at 5 ft. ;

and its three limbs have a circumference of 13 ft. 3½ in., 13 ft., and 10 ft. 7½ in. respectively (July 1903). Another Sweet-Chestnut on the same estate girths 23 ft. 3 in. at 5 ft. up.

Growing as a timber-tree in close canopy, however, it does not usually attain large dimensions, unless it has the advantages of a good loamy soil and a sheltered situation. It is therefore not generally suited for planting for profit on an indifferent soil or in an exposed situation.

The full and rich green foliage of the Sweet-Chestnut has a fine effect in early summer, and in autumn it takes on a pale-yellow colour contrasting well with that of the foliage of most other trees. When young, Chestnut grows very rapidly and soon attains a large size; but it seldom reaches large size without becoming *ring-shaken* in the heart, and consequently useless for many technical purposes. In France 60-year-old trees often girth over 5 ft.

For coppice and underwoods Chestnut is one of the best of all our trees, unless the soil be limy; and where there is a demand for hop-poles and small material, it pays well. It throws up suckers as well as a strong flush of stool-shoots, which grow very rapidly, and sometimes measure from 20 to 30 ft. in height, and 4 to 5 in. in diameter, at eight to ten years of age.

Economic Value.—The wood of the Sweet-Chestnut has a mean specific gravity of 0·99 when green and 0·66 when seasoned, so that it weighs about the same as Sycamore and Birch. It is a very tough and durable kind of timber, and lasts even better than Oak or Acacia when used as poles or posts in the ground. Many old beams in churches, long supposed to be Oak, are really Chestnut. It makes beautiful flooring or wainscoting and furniture, somewhat lighter in colour than Oak, but often very prettily flowered and marked. It is well suited for cart-poles and waggon-shafts, also for gate-posts and general fencing purposes. One of the best of the movable kinds of light wooden fences now used in England consists of thin wire-bound palings of split Chestnut, imported from the south of France.

In England, however, the tree is very liable to heart-shake, so that its timber-producing capacity is of far less importance than its suitability for coppice-growth. It has a remarkably good reproductive power, and while the stronger coppice-poles furnish good material for hop-poles and the like, young shoots yield first-class hoops for casks, material for hurdle-making, &c.

Throughout Central Europe the wood of the Chestnut is principally used for the manufacture of staves for casks, and large quantities of it are utilised thus and for vine-props in the warmer wine-districts, along with Oak.

Soil and Situation.—The soils most favourable to the Sweet-Chestnut are those of a light, deep, fresh, or moist character, which need not be possessed of any great amount of mineral strength, but must not be wet. It does not thrive on stiff clay or cold-bottomed land. In Britain a sheltered site and a well-drained soil, even if stony or gravelly and rather poor in quality, produce a better growth of Chestnut than cold wet land. A native of warm climates, it grows best in the central and southern counties of England as underwood to Oak standards in copse-woods, and particularly on warm southern exposures or undulating ground. It thrives best on land rich in potash, but even a very slight percentage of carbonate of lime throughout the soil affects its development; hence sandy or loamy tracts suit it better than those of a limy nature. Young plants are apt to be damaged by late frosts; but its reproductive capacity being strong, the damage is soon repaired.

Cultivation.—The Sweet-Chestnut is propagated in the same manner as the Oak, except that young Chestnut is usually of more rapid growth, and is therefore ready for planting into the woods after having stood for two years in the nursery-rows. As the nuts seldom attain good germinative capacity here, it is best to procure from abroad any supply that may be required. The nuts being larger, they should be sown more thinly than acorns, but should be covered rather more deeply with earth, say not less than fully $1\frac{1}{2}$ to 2 in. They should always be sown *point downwards.*

On the Continent yearling seedlings and two-year-old plants are often put out into the woods, whilst older material must first be transplanted into nursery-beds for two or three years. The seed is sown in drills about 1 ft. apart in the nursery-beds, each seed being inserted point downwards at a distance of from 3 to 4 in. in the drill, and covered over with about $1\frac{1}{2}$ in. of earth, care being taken not to plant the nuts too deep. At one-and-a-half, two, or two-and-a-half years of age, these seedlings are removed and put out in the woods. Owing to the early movement of sap in spring, many prefer that planting should take place in autumn; but where late frosts are to be feared, early spring planting is preferable. Owing to the higher cost, the use of transplants put into the nursery-beds at one or two years of age is confined to the filling of blanks in young plantations, or to ornamental plantations.

Sylvicultural Importance of Sweet-Chestnut.—Although the Chestnut has much in common with its close relative the Oak, yet it can thrive with less light, and in this particular respect it certainly has more in common with the Beech than the Oak. Thus, if grown in highwoods, it remains long in close canopy though the stems only attain a large girth when grown in comparatively free enjoyment of light, air, and warmth. But in Britain its sylvicultural value is mainly confined to its favourable characteristics as coppice-growth or underwood. In power of producing shoots from the stool it is not equalled by any of our other trees, as stools of any age up to 100 years yield a good flush of strong shoots. And like the English Elm, an equally poor producer of seed in our climate, the Chestnut is compensated by nature through being enabled to throw out root-suckers as well as stool-shoots. These suckers easily bear transplanting, and can develop into sound trees capable of attaining a great age.

On somewhat poor soil the Chestnut yields as coppice perhaps higher returns than any other kind of underwood. Its strong reproductive capacity can be stimulated by felling low, and heaping earth on the stools. When pure coppice has been formed by sowing or planting Chestnut, it should be cut over for the first time at ten years of age, in order to strengthen the stools; and if worked thereafter with a rotation of fifteen years, it yields a good return in stout poles, if such can be favourably disposed of. Where smaller material finds a better market, there is less danger of the soil deteriorating under this than under most other kinds of coppice-crops. The thick annual fall of foliage forms good *humus*, while shoots come vigorously from the stool and keep the soil cool and moist by their thick flush of foliage. For climatic reasons, however, the Chestnut can only be expected to yield its best results in the warmer tracts of England, where its cultivation deserves more attention than has hitherto been paid to it by landowners.

The seed should only be sown in spring, in order to minimise the danger from mice, birds, &c., and also to obviate damage by late frosts to a certain extent. For the formation of underwood, *dibbling* the nuts at 2 ft. by 2 ft. or 3 ft. by 3 ft. is often a cheap method; while the plashing or layering of shoots up to the thickness of the wrist is an excellent way of helping to fill up blanks in thin coppice. But unless supplies of fairly good seed are easily obtainable, planting is often preferable to sowing.

OLEACEÆ LINDL.

To this comparatively small family belong the Ash, the Lilac (*Syringa*), the Privet (*Ligustrum*), and the Olive-tree (*Olea*).

4. THE ASH, *Fraxinus* (LINNÆAN SYSTEM, POLYGAMIA DIŒCIA).

Generic Character.—*Flowers* polygamous. *Calyx* none, or 4-parted, or 4-toothed. *Corolla* none. *Stamens* 2, in the male flowers. *Anthers* sessile, or on short filaments, dehiscing outwardly. *Female flowers* the same, except that they have no stamens, but have each a pistil that has a bifid stigma. *Fruit*, or samara, 2-celled, compressed, winged at top. *Cells* 1-seeded (Loudon).

There are about twenty-five to thirty distinct species of the Ash, the greater number of which are natives of North America, though many of them are chiefly to be found in Central and Western Asia and around the basin of the Mediterranean Sea; but only the Common Ash (*Fraxinus excelsior*) is indigenous to Britain, or throughout Central and Northern Europe. Even under favourable circumstances, the others attain small dimensions as compared with the Common Ash, which is one of our most useful hardwoods for general purposes. It is the only species that need be referred to here, none of the others being suitable for cultivation with a view to profit.

It may be remarked that the leaflets of the pinnate leaves are borne on small petioles or leaf-stalks in most of the North American species, while they are sessile in all the European species.

THE COMMON ASH, *Fraxinus excelsior* L.

Specific Character.—The leaves have generally five pairs of leaflets, but sometimes six. *Leaflets* almost sessile, lanceolate-oblong, acuminate, serrated, cuneated at the base. *Samara* obliquely emarginate at the apex. The *Flowers* are naked, and produced in loose spikes from the sides of the branches. On some there are only female flowers; on others, hermaphrodite ones; and on others, male ones; while on some trees the flowers are found in two of these states, or in all of them (Loudon).

Distribution.—The Common Ash is to be found growing all over the British Isles. The northern limit of its spontaneous distribution extends from 63°40′ in

Norway to 61° in Sweden and 62° in Finnland, trending thence south-eastwards across Central Russia to Rjäfan. From here it strikes north-east again to Kasan, where its eastern limit begins, and continues thence in a south-westerly direction across the Steppes and by a circuitous curve to the Crimea, where its European limit ends; but in the Transcaucasian districts it begins again, and continues eastwards into Central Asia. Its southern limit runs from Asia Minor to Turkey, thence across the Adriatic, Italy, and Southern France to the Pyrenees and Northern Portugal (Willkomm). This proves that, so far as climate is concerned the Ash is a species that can stand not only extreme winter cold, but also a very high degree of summer warmth. In low-lying moist localities, however, it requires nurses to protect it against late frosts, and in this respect is very sensitive.

Description.—The Common Ash is certainly one of the most graceful and beautiful of our timber-trees, whether growing in park, plantation, or hedgerow; and its pinnate foliage contrasts well with the differently shaped leaves of our other trees. Some object to it, however, on account of its only coming into leaf about the end of May, when most other trees are in almost full leaf. It is also unfortunately the first tree to lose its foliage in the autumn, for the early night-frosts soon bring down all the leaves. But even when thus stripped bare, its appearance here and there as a leafless tree contrasts picturesquely with masses of more or less withered foliage upon the neighbouring trees. In early summer the young foliage is of a very soft and beautiful light-green colour, with a suggestion of blue in it; and during the winter the dark buds on the compressed young shoots are of a rich deep black.

In plantations of moderate density the Ash attains a good height and forms a smooth, clean, cylindrical stem, though without assuming a girth proportionate to its height. Even in rather thin and open plantations the formation of side-branches may easily be checked; for the Ash is, except during the first few years of its growth, a **light-demanding** tree, impatient of side-shade. When growing in a park or lawn, it forms a large-headed tree of imposing effect, and with a big stem quite in proportion to its massive crown.

Although in many respects a hardy tree, Ash does not attain any very great longevity, though trees of over 300 years exist in several parts of the country, while others, still in healthy growth, are known to be upwards of 200 years old. At Longleat, in Wiltshire, there are several Ash with clear stems of nearly 50 ft., and measuring from 10 to 14 ft. in circumference. In many other parts of the British Isles there are fine specimens of old Ash-trees measuring up to 15 to 20 ft. in circumference and bearing a proportionate crown of foliage.

One of the distinctive characteristics of the Ash is its frequent tendency to forked growth, as may easily be seen by following along the main branches from their base towards the youngest growth of twigs. This is due to the shoot within the terminal bud getting nipped by frost, while the buds which open later are spared. Its growth in height is most energetic between the twentieth and fortieth year, and its increment in girth greatest during the succeeding twenty years, its full maturity being here reached about the age of fifty to sixty years.

Economic Value.—The Ash is the toughest and most elastic of our timbers, and it can be used for more purposes than the wood of any of our other trees. It has a sp. gr of 0·88 when green and 0·75 when seasoned, so that it is always floatable. It is of special value for agricultural implements, furniture, cart-making, and coach-building; and the smaller material yielded by coppices is most useful as hop-poles, hoops, hurdles, crates, &c. It makes the best of oars and the toughest of shafts for carriages.

Wherever the soil suits its cultivation, Ash is one of the most profitable of the hardwoods that the landowner can plant. Besides being quick in growth, it finds its use at all sizes, even from the sapling or the two-year-old coppice-shoot. The finest Ash is that grown in the Midlands, for the better classes of which as much as £11 per ton of 40 cub. ft. is paid by coachbuilders. But so little first-class Ash is now obtainable in England, that in 1901 the Coachbuilders' Association memorialised the President of the Board of Agriculture to try and stimulate landowners to grow more of this valuable timber, as English Ash is better in quality than what is imported from other European countries or from America (vide *Journal of the Board of Agriculture*, January 1902).

Soil and Situation.—The Ash is in all respects a hardy tree, which accommodates itself to most kinds of soil and to situations not too high-lying and exposed. To grow it to the best advantage, it should, if possible, be planted only on a fresh, deep, light, loamy soil; and it will thrive all the better if the soil contains a fair admixture of *humus* or leaf-mould formed from the dead foliage annually cast to the ground. On binding argillaceous soil, or on dry porous sand, it is apt to develop indifferently, and to show early signs that the situation is unfavourable to its normal requirements in nutrients and moisture. Ebermeyer's investigations (*Forstlich-naturwissenschaftliche Zeitschrift*, 1893, p. 230) show that it is the most exacting of all our forest-trees as regards mineral food. It also exhibits far higher demands than the majority of our woodland trees as to the quantity of water required to maintain a normal rate of transpiration through the foliage; and it is on this account that the foliage dries up and falls off more quickly in autumn than is the case with most other trees. No situation is better suited for growing Ash than the sides of ravines with a good strong loamy soil, where soil-moisture percolates gradually downwards from the ground above; and even in such cases the best and largest trees will be found on the lower parts, where the shelter is greatest and the soil deepest. In damp low-lying localities it is apt to be damaged by late frosts, and may even require the aid of nurses for the first few years; but when it is planted on fresh uplands, with free circulation of air, its lateness in bursting into leaf usually affords it ample protection against frosts during the spring. On unsuitable soil Ash turns black in the heart and cankered in stem and branches from an infectious disease caused by a fungus (*Nectria ditissima*), which often causes great damage.

Cultivation.—The Ash is raised from seed, while varieties are propagated by grafting and budding on plants of the same species. From about the fortieth year onwards, and earlier in trees growing in the open, it seeds freely and almost annually; while as regards seed-production, Ash and Sycamore may be classed together as being the most prolific of English hardwood trees. The dry winged fruits enclosing the seeds, and forming bunches of "keys," are generally fit for gathering about the end of October. If left on the tree they often hang there throughout all the winter, until the following spring, or even into the summer months. If sown in autumn, they sometimes germinate in the following spring; but if left to fall from the tree, they usually remain for a whole year or longer before sprouting. Hence it is generally advisable to store them for a year, so as to increase their chance of germinating soon after being sown.[1] In the second March after collection, the seeds should be sown rather thinly in rows (say one seed to every 3 sq. in.) upon moderately pulverised soil, when they are almost sure to come up well. The covering of earth given to them should not exceed $\frac{1}{2}$ to $\frac{3}{4}$ of an inch. In the following spring the plants will be ready for transplanting into the nursery-rows. These should be about 15 in. apart, whilst the distance from plant to plant in the rows should be about 4 in. Having stood there two years they may be removed for planting in the open, unless kept for another year to form saplings of extra size. Their growth in height is usually slight during the first year, but becomes rapid from the second year onwards.

The leading **Sylvicultural Characteristic of the Ash** is the emphatic demand it makes with regard to light, as is shown in the thinness of its foliage and the sparseness of its crown. Hence, unless worked with a low rotation, it is little suited for forming pure forests, or even large groups or patches of trees of its own species, whether raised from seed or from stool-shoots or suckers. This characteristic is not so strongly marked in Britain as on the Continent, because here the tree is most frequently to be seen under circumstances favourable to its growth—on moist tracts, or as a hedge-row-tree on fertile soil at the edge of fields (where, however, it robs the agricultural crops of a good deal of nutriment with its network of shallow surface-roots ramifying throughout the upper layers of the soil).

In its young state, as may be seen in underwoods, the Ash can bear considerably more shade than the Oak, though later on, after the pole-stage of growth, it becomes the more light-demanding of the two trees. But as it is generally grown only on good fresh soil, where all kinds of trees are least intolerant of shade, this characteristic is less apparent than it otherwise would be.

The proper position of Ash is that of a subordinate tree scattered throughout a matrix of other trees of somewhat slower growth, and better able to overshadow and protect the soil. On many a hillside Ash may be grown with profit near small watercourses; and on good, but rather moist,

[1] When gathered for storage previous to sowing in the nursery, Ash seeds should be mixed with dry sand, and kept for about eighteen months, so as to rot off the outer coat; and to ensure this more effectually, the whole mass of seeds and sand should be turned once every three months. This mass should not be much over 1 ft. in depth, as otherwise it is apt to become heated, when the seed loses its germinative power.

low-lying soil it can often give fair returns when grown along with Oak, Maple, Sycamore, and Elm, or even with Willows and Alder on wet land. In such localities the trees not only have a thicker crown of foliage than on drier land, but there is also less danger of the soil deteriorating through the action of sun and wind. When grown along with the Oak on fresh soil, the Ash should be cut out about the sixtieth year, when it will have reached its maturity, and when, at the same time, it may perhaps be necessary to form underwood below the Oaks. On such better classes of soil the Ash, Sycamore, and other trees cut out often throw up a sufficient crop of stool-shoots and root-suckers to form a natural underwood, that can be made thicker by planting and plashing.

The Ash is well suited for standards or overwood in copse, and soon attains good development. As underwood, when not heavily overshaded, it also yields good returns, and reproduces itself easily.

Where the Common Alder forms the ruling species on wet soil, the Ash can often be treated in very much the same manner as Oak grown along with Beech, and can then often be introduced in larger numbers than would be wise on drier soil. On such marshy land the Alder may be coppiced, whilst the Ash remains to thicken as a standard. In other classes of woods formed of broad-leaved kinds of trees, the Ash should merely be sprinkled individually among other trees more capable of protecting the productivity of the soil. In such cases, and in fact wherever it is intended to allow it to develop into large timber, it is always best to plant it, because stool-shoots and suckers (though these soon develop independent root-systems) culminate earlier in growth than plants raised from seed. At first young seedling transplants require careful protection against rank growth of grass and other weeds; but as they rapidly shoot up when once they have established themselves in the ground, weeding operations are soon no longer requisite. Endowed with a strong recuperative power, the Ash quickly outgrows injuries received from cattle, &c.

The various American species of Ash—the chief of which are the White Ash (*Fraxinus Americana*), the Oregon Ash (*F. Oregona*), and the Green Ash (*F. viridis*) — have much the same characteristics as our Common Ash with regard to toughness and durability. The White Ash is the best for growing on dry soil, and the toughness of its wood makes it of special value for oars; while the Oregon Ash, from the Pacific coast, grows so rapidly in height that it is said to hold its own with the Larch in a plantation in Yorkshire. The White Ash has the advantages over our indigenous species that, instead of lying over for a year, its seed germinates during the year after it ripens, that seedlings are able to stand severe frost in spring (as the leaves are later in flushing), and that it will grow quickly on poor soil not good enough for the Common Ash. In Germany it has also been found to bear temporary inundation during summer.

ULMACEÆ Mirb.

This family consists of eight genera; but only one of these is represented in Europe, all the others belonging to tropical lands.

5. THE ELM, *Ulmus* (Linnæan System, Pentandria Digynia).

Generic Character.—*Flowers* in lateral groups, proceeding from peculiar buds, and protruded before the leaves; bisexual; monœcious. *Calyx* reddish, distinct from the ovary, top-shaped or bell-shaped, of one piece, but having 5 or 4-8 segments, which imbricate in æstivation; remaining until the fruit falls. *Stamens* as many as the segments. *Style*, short or wanting. *Stigmas*, 2, acuminate. *Fruit*, a samara, with a membranous wing (Loudon).

There are several species of Elm, from the Siberian Dwarf (*Ulmus pumila*), growing only to about 4 ft. in height, to the English Elm (*U. campestris*), which often reaches a height of 100 ft. Several North American species also form large trees, but they are not suited for cultivation in Britain, though occasionally found as ornaments in pleasure-grounds. There is a great want of unanimity, and no small amount of confusion, in the nomenclature of the Elms. But, as Purkyne conclusively proved, only three species of this genus occur of spontaneous forest growth, and all the others are merely varieties or hybrids. These three species are, *U. campestris* Sm., *U. effusa* Willd., and *U. montana* Sm., all of which appear to have been originally comprised within the species *U. campestris* L. And as it not infrequently happens that certain of the characteristics of these three species are interchangeable, it seems desirable to confine attention to the two species showing more or less constant and characteristic differences—(1) the *Ulmus campestris* Sm. and (2) the *U. montana* Sm.—as these are the only two of interest to the forester in Britain.

(1) COMMON ENGLISH or SMALL-LEAVED ELM, *Ulmus campestris* Sm.

Specific Character.—*Leaves* doubly serrated, rough. *Flowers* nearly sessile, 4-cleft, brownish; March and April. *Samara* oblong, deeply cloven, glabrous, yellow; ripe in May (Loudon).

The English Elm, which was introduced by the Romans, is easily distinguished from the Scots Elm (*U. montana*) by its slender young shoots, and by those of the last year springing alternately from each side of the preceding young shoots (see Figs. 4, 7). The buds and leaves also all spring alternately from the young shoots. The beautiful dark-green leaves are small as compared with those of the Scots Elm. They are doubly serrated, rough and hard to the touch, and usually very unequal at the base,—although such inequality is more or less characteristic of all species of Elm.

Distribution.—The Common Elm is the only species indigenous to Central and Southern Europe, where it attains its finest development. From Spain and Algiers it extends along the Mediterranean, and thence eastwards into Siberia and the valley of the Amur. In Southern Europe it forms large forests; but even so little to the north as Hungary it ceases to be of true forest growth, and gradually gives place to the northern species, *U. montana*.

Description.—Elm is, next to the Oak, the tree most generally cultivated for ornament in England. It reaches its perfection in parks, avenues, and hedgerows. It is the most characteristic hedgerow-tree throughout many of the southern and south-western counties of England, where it attains its finest growth. It is the tallest and most graceful of our trees for park scenery. In favourable situations it grows rapidly, sometimes reaching 25 ft. in height in ten or twelve years after being planted; but in general, and especially on poor soil, it is less rapid in growth than Wych Elm. It has a tall, upright habit of growth, and forms a straight stem, measuring from 3 to 5 ft. in diameter when mature, with branches often slender in proportion to the diameter of the trunk. Even during warm wind-still weather, as well as during gales and high winds following heavy rainfall, the large branches are apt to fall to the ground.

Fig. 4.

Young shoot or spray of English Elm in winter (U. campestris).

In England the Elm attains large dimensions. At Syon House, Isleworth (Middlesex), there are trees upwards of 100 ft. high, with stems from 5 to 8 ft. in diameter, forming large and spreading tops of grand and imposing aspect; while at Longleat, Wiltshire, there is one 120 ft. high, with a circumference of 20 ft. at 4 ft. from the ground.

Some of the most celebrated Elms in Europe are in Germany. The largest is that on the village green at Schimsheim near the Rhine, in Hesse, which is said to be between 500 and 600 years old, and is still flourishing, although rotten and hollow in the bole. It is 100 ft. in height, and has a girth of 44 ft. at $3\frac{1}{3}$ ft. above the ground. At Gölbheim, in the Rhine Palatine, the Elm is still vegetating under which the Emperor Adolph fell in battle in 1298.

Fig. 5.

Leaf of the English Elm (U. campestris).

Economic Value.—Elm timber is particularly strong in lateral fibre, but is deficient in longitudinal adhesion. Owing to its finely marked grain, it is a handsome furniture wood, and it is the chief wood used for coffins. Its strength in lateral fibre fits it admirably for naves of wheels and for blocks and dead-eyes for the rigging of ships. Before the days of metal and earthenware pipes it was largely used for water-conduits, and it is still used as troughs for conveying and retaining water, and for supporting the banks of watercourses, &c. In Gloucestershire, where it perhaps attains its finest growth, the timber sells at 10d. to 1s. 4d. per cubic ft., which is more than is there obtainable for Scots or Wych Elm.

It has a sp. gr. of 0·95 when green and 0·69 when seasoned, so that it is hardly floatable immediately after felling. When grown on warm southern exposures, it yields a very durable wood, ranking not far behind Oak; but on less favourable situations its timber is not so durable. Its many excellent technical qualities, and its fine texture and colour, as well as its rapid growth, entitle it to a fair share of attention on land favourable to its growth.

Soil and Situation.—Ebermayer's investigations have proved that Elms are not only exacting with regard to mineral nutriments, but also require a large quantity of soil-moisture to replace the water transpired rather freely through their foliage. Though often to be seen thriving well on what appears to be light and rather dry land, Elms in reality require a fresh soil; and it is only because the general quality of such apparently rather dry land is good, and because Elm-trees have deep heart-shaped roots, that they grow so well. In general, like the Ash, Elm grows best on fresh or even damp soil; and although it naturally prefers light sandy loam, yet Elm can even thrive when the soil is somewhat too binding for Ash. A warm, sunny exposure is, however, under all circumstances essential for producing the best quality of timber. The Elm is rather a tree of the plains and of undulating uplands than a denizen of the hilly tracts, where other species yield better sylvicultural results.

Cultivation.—In Southern Europe the Elm is raised from seed. As our summers are rarely warm enough to produce good seed, supplies have usually to be imported. It may also be propagated from root-suckers, which are formed in abundance and can easily be detached and transplanted, or by means of layers, the method mostly adopted in British nurseries for the propagation of this tree, and of great use in helping to fill blank spaces in coppices.

Even where indigenous, this Elm produces seed having a low germinative capacity of only about 40 per cent, and this becomes lower still by storage, or by packing and transport even for a very short time. Hence the method of regeneration by means of layering has much to recommend it; and it is to its strong reproductive capacity by stool-shoots and suckers that the Elm has been able to maintain itself so vigorously in England in spite of its poor seed-production. The formation of suckers is favoured by felling as nearly flush with the ground as possible. When home-grown seed is procurable during a warm, dry spring, it should be sown at once, as it germinates within three to four weeks after ripening. Seed that has been stored over one winter, besides having a very low germinative capacity, is apt to remain inert in the soil for a year before any seedlings come up at all.

Young Elm plants are decidedly hardy, and suffer but little from late frosts. But as the sap begins to rise early in spring, planting should take place in autumn rather than in spring. The growth of the young plants is rapid, a height of 10 ft. often being attained in six years. As they are endowed with considerable recuperative power, large plants have little difficulty in establishing themselves satisfactorily after being transplanted.

The Sylvicultural Treatment of the Elm in many respects closely resembles that of the Ash, Maple, and Sycamore, as it is essentially a **light-demanding** tree. It is just as little suited for forming pure woods, or large groups, as other light-demanding trees. When once it has completed its main growth in height, it needs increased space for expanding its crown; and long before it becomes really mature, its light canopy of foliage is insufficient to protect the soil against the deteriorating action of sun and wind. On the Continent it is generally to be found sprinkled in single stems throughout mixed crops, in which the Oak, Ash, Maple, and Sycamore are placed amid a matrix of Beech or other shade-bearing tree suitable to the soil and situation, and may then by about the eightieth year yield stems of good marketable dimensions. On the better classes of soil, where the proportion of Oak is larger, and where it is intended to have ultimately a pure crop of mature Oak, Elm may be introduced along with Ash, Maple, and Sycamore, and then cut out between the sixtieth to eightieth year, so as to permit the Oaks to have the undisturbed enjoyment of a larger growing-space and fuller supplies of light and warmth. Such woods will often in Britain, and especially in the south of England, require no artificial formation of underwood, as the Elm, Ash, and Sycamore removed often exhibit a strong power of coppicing, and a capacity for bearing shade which at first sight seems at variance with their true character as **light-demanding** trees.

As a standard tree in copse the Elm is not so well suited as Oak or Ash, for its shade is often heavy; and at the same time it is not so profitable as these.

Among coppice-growth the Elm is well able to maintain itself, and bears a considerable amount of shade on good fresh soil. But as it is of rapid growth and has a tendency to spread itself out at first, this expanding habit often requires to be restrained in favour of the more profitable Oak, Ash, Chestnut, &c.

(2) MOUNTAIN, SCOTS, or WYCH ELM, *Ulmus montana* Sm.

Specific Character.—*Leaves* pointed, rough, broad, and doubly serrated. *Flowers* on longish peduncles, loosely tufted, 5-6-cleft, reddish, April and May. *Samara* somewhat orbicular, slightly cloven, naked, brown; ripe in June. *Branches* drooping at their extremities; their bark smooth and even (Loudon).

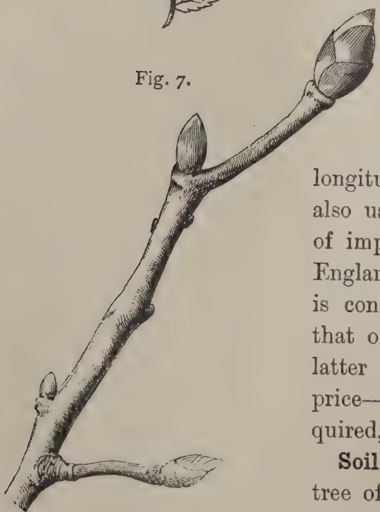
The Wych Elm (Figs. 6, 7) is easily distinguished from the English Elm by the greater length, breadth, and roughness of its leaves, which have also a longer point and are more deeply serrated. The young shoots are stronger and more massive, but far less regular and formal, than those of the English Elm, and they are slightly pubescent or downy in their first stages of growth. A very distinctive characteristic of the Wych Elm is its incapacity for producing root-suckers, while the English Elm, on the other hand, seems in our climate to be endowed with this reproductive power to compensate it for the want of a sufficient amount of warmth to enable it to form and ripen seed-buds during ordinary years.

Distribution.—The Scots Elm is indigenous to Britain and other parts of Europe. In Scotland it thrives better than the English Elm, for which the average summer warmth seems hardly sufficient. It is also grown extensively in Ireland; but in England, as on the Continent, the Common Elm is preferred.

Description.—The Wych Elm forms a large-crowned and spreading tree, with strong, diverging limbs, contrasting well with other trees of a stiffer and more rigid character. These side-limbs are often so heavy that they split the trunk, unless removed by pruning. Trees of 80 to 90 ft. high, and 3 to 5 ft. in diameter, are common in many parts of our island. When the tree has arrived at full maturity, the branches, from their great weight, droop at their extremities and form rich festoons when in full leaf. As an avenue or park tree, it seldom attains such height or cleanness of stem as the English Elm; but in the woods this more branching habit is checked, and it produces a large quantity of clean timber. It is of much quicker growth than the English Elm, and this difference in the rate of growth is perhaps most marked on poor soil. When young it is generally of a rambling, straggling habit, until its leader becomes fairly developed; but after that it assumes a more upright growth, and soon attains a considerable height.

Fig. 6.

Fig. 7.



Leaf and twig of the Wych Elm (Ulmus montana).

Economic Value.—Wych Elm-wood is used in Scotland for many rural purposes to which Ash is generally applied in England. It serves for cart and waggon shafts and naves, wheelbarrow and cart framing, &c., for all of which it is well adapted owing to the toughness of its longitudinal fibre. Large quantities of it are also used for railway purposes and for handles of implements. In Scotland and the north of England the timber produced by the Wych Elm is considered stronger and more durable than that of the English Elm, but in England the latter is preferred, and commands the better price—although where toughness of fibre is required, Ash is decidedly preferable.

Soil and Situation.—The Scots Elm is a tree of the hilly tracts. It thrives well in glens and ravines with well-drained soil, where it can get its deep side-roots easily down into the subsoil, and where moisture is constantly percolating downwards; but it does not succeed if its roots get into stagnant water. The largest trees are usually to be found near the side of a stream, where the roots have ample supplies of water without its lodging about them, and where the soil is a porous sandy loam. It grows better on a stiff loam than on loose sandy or gravelly land; but the best trees are almost always to be found on soil of a medium description.

Cultivation.—Wych Elm-seed is generally plentiful on old trees from the end of May to the middle of June. Flowering takes place in March and April, before the spring flush of foliage; and the seed ripens about the end of May or the beginning of June. It is shed at once, and soon germinates if it happens to alight on favourable soil. If gathered and sown out in the woods directly, the young seedlings may attain a height of from about 6 to 9 in. by the autumn. Even when trees are growing in the open, good seed is seldom produced before about the thirtieth year; but after that it seeds freely almost every year, though at all times its germinative capacity is small, 45 per cent being a very good yield in experimental tests.

As the seed is very light and apt to be blown away by wind, it should be gathered by hand from the tree as soon as ripe and sown immediately, as it will not keep long. It should be sown in rows 15 in. apart in the nursery, upon a fine light soil, and not covered to a greater depth than a quarter of an inch at the very most, although anything like so much is not requisite. The seedlings spring up very freely and quickly, and will be ready for transplanting into the nursery in the following spring in rows about 20 in. apart, and with the plants about 4 in. from each other. After standing here for two years they will be ready for planting out.

ACERINÆ DC.

6. THE MAPLE, *Acer* (Linnæan System, Polygamia Monœcia).

Generic Character. — *Sexes* hermaphrodite, or monœciously polygamous. *Flowers* with a calyx and corolla. *Calyx* divided into 5 parts, or some number between 4 and 9. *Petals* the same in number. *Stamens* 8, or some number between 5 and 12. *Anthers* 2-lobed. Carpels 2, very rarely 3, each a *samara* or "key" (Loudon).

There are altogether about 81 species of Maple, most of which inhabit the temperate zone of North America, and of which 8 occur in Central Europe. The Field Maple (*A. campestre*), a species indigenous to Britain, is common as a shrub or small tree in hedgerows throughout Central and Southern England, where its 3- to 5-lobed leaves take on a beautiful red colouring in the early autumn. It is also found growing wild in coppices and underwoods. But only 3 species are here worth referring to—(1) the Sycamore or Great Maple; (2) the Norway Maple; and (3) the Sugar Maple of North America.

These three species are distinguishable as follows :—

1. Flowering occurs after the complete flushing of the foliage in spring. Leaves 5-lobed. Flowers in pendulous racemes. **Sycamore** . *A. Pseudo-platanus.*
2. Flowering occurs simultaneously with, or shortly before the flushing of, the foliage in spring. Leaves with five or seven lobes.
   - (*a*) Young shoots and leaf-stalks exude a milky sap when broken. Samaras (winged carpels) of the fruit extending far apart. **Maple** . . *A. platanoides.*
   - (*b*) Sap of young shoots and leaf-stalks not of a milky nature. Samaras upright or close together. **Sugar Maple** . . *A. saccharinum.*

None of these are indigenous to Britain, though the two first-named have long ago become thoroughly naturalised.

(1) SYCAMORE, GREAT MAPLE, or SCOTS PLANE, *Acer Pseudo-platanus* L.

Specific Character.—*Leaves* cordate, smooth, with 5 acuminated, unequally toothed lobes. *Flowers* greenish-yellow, mostly hermaphrodite; May and June, in pendulous racemes, rather compound; with the rachis, as well as the filaments of stamens, hairy. *Fruit* smooth, with the wings rather diverging, reddish-brown; ripe in October (Loudon).

Distribution.—The Sycamore is indigenous to all Central and Southern Europe except the extreme south-east or south-west parts. It attains its finest development in the central area occupied by Germany, Switzerland, Austria, and Italy, where it is found chiefly on the hilly tracts. It is not a native of Britain, but was introduced during the fifteenth century, and has found climatic conditions so favourable to its requirements that it is as hardy as any other tree.

Fig. 8.

Leaf of the Sycamore (A. Pseudo-platanus).

Description. — It is easily distinguishable from the Maple in summer by its foliage[1] (compare Figs. 8 and 9), and in winter by its having yellowish-green buds, whilst those of the latter are of a reddish-brown,—likewise by its scaly trunk, which often closely resembles in appearance the stem of the Plane-tree (whence its common name of "Plane" in Scotland); but it differs from the latter again by its buds being arranged opposite to each other on the twigs, and not alternating as in the true Plane.

It is a large tree of rapid growth, which lives to a great age. Its leaves being large, it presents a heavier mass of foliage than most other trees, and is therefore often considered too heavy and formal for introduction into landscape where graceful outlines are desired. It has, however, the advantage of coming into leaf earlier than most of our other trees; and in summer its great unbroken mass of foliage contrasts well with other trees. Unless grown in the close canopy of woods, the Sycamore has a strong tendency towards almost horizontal ramification, and in a park or on a lawn its short massive stem carries a large spreading head. When introduced into Beech-woods it soon shoots ahead, but requires protection later on. Though not absolutely *light-demanding*, it can hardly be classed as a shade-bearing species, although in our British woods, mostly on good fresh soil, it bears far

[1] The foliage is very liable to be damaged and rendered unsightly by a fungous disease due to *Rhytisma acerinum*, which, however, exerts no noticeable influence on the rate of growth or the quality of the wood formed. But as it is infectious, and a blemish from an arboricultural point of view, all those black-spotted autumn leaves should be swept together in heaps and burned, in order to prevent the spread of the disease.

more shade than would be possible for it to endure on true forest land of indifferent quality only. It presents a dense mass of foliage to the eye, but the leaves in the interior of the crown are not nearly so numerous as in the more shade-enduring species (*e.g.*, Beech). Being exceedingly hardy, except as regards frost in low-lying localities, and coming very early into leaf in spring, it makes a good hedgerow-tree and affords considerable shelter to the fields, though it must be admitted that it casts a good deal of shade over the land.

Both in England and Scotland there are many fine Sycamore of from 70 to 100 ft. high, and with stems from 6 to 8 ft. diameter; and some are considerably larger. The largest known to me in Ireland girths 18 ft. 9 in. at 5 ft. up (Rossanagh Park, Ashford, Co. Wicklow). It completes its growth in height about the seventieth to ninetieth year in close forest, though much sooner in the open, after which it expands in diameter.

Economic Value.—The Sycamore is frequently a very valuable tree, large stems often being sold at rates varying from 2s. to 3s., and even 5s. to 6s., per cubic ft. The highest price is given for well-grown stems, for rollers in calico and jute mills, near milling centres (such as Dundee), and in the case of suitable timber of this class Sycamore is one of the most profitable of our trees at present. The timber is of excellent quality if used in dry places; but when merely of small size it is not of much value. Sycamore is also largely used for furniture, wooden dishes, ends for herring-barrels, &c., and by turners and toy-makers. It is somewhat finer in the grain than the wood of the Maple. It has a sp. gr. of 0·93 when green and 0·66 when seasoned, so that it is floatable soon after being felled and logged.

Soil and Situation.—Ebermayer has proved from analyses of leaves that both the Sycamore and the Maple make considerable demands for mineral nutrients (especially potash and phosphoric acid). In this respect they are more exacting than Beech, Willow, or Oak, although not so exacting as Elm, and considerably less so than Ash, the most exacting of all our trees. At the same time their requirements as to water for transpiration are large, like those of all other deep-rooting species of trees; and, as might be expected, they are greater in the case of the Sycamore, with its more pronounced tap-root, than of the Maple.

Experience shows that the Sycamore, to be grown for profit in woodlands, must have either a deep soil or a fissured subsoil for the proper development of its deep-going root-system. Given a favourable subsoil, however, the quality and nature of the surface-soil is of comparatively little importance. Sycamore is more a tree of the hilly tracts than the Maple, which is rather the tree of the plains and uplands merely; but while the former grows well on moist soil fringing the water-channels on hillsides, it is less able than the Ash and the Maple to thrive where the soil-moisture is sluggish or stagnant. Dry light soil is not really suited to it; nor does it find favourable conditions of growth on heavy, binding, or wet land, although merely temporary excess of moisture does it no permanent injury. Though Oak, Maple, Elm, Sycamore, &c., may often be found growing in mixed woods on flat land, yet whenever anything but the better classes of soil are being dealt with Sycamore is preferable for planting on hilly land, and the Maple on lower-lying localities, where young Sycamore are apt to suffer from late frosts in spring. A fair amount of lime throughout the soil is favourable to the growth of both species, but more especially of the Sycamore.

Cultivation.—The Sycamore is grown entirely from seed, except variegated and other varieties reproduced by budding or grafting. It produces large quantities of seed, and is (along with the Ash) one of the most prolific seed-bearers among hardwoods. Seed-production begins very early on coppice-shoots, and commences about the twenty-fifth to thirtieth year on trees in the open, though not until about the fortieth year on trees growing in close canopy.

As soon as the seeds ripen in September or October, they should be gathered and sown immediately, as their germinative power soon diminishes. If the seed be kept over winter, it should be mixed with dry sand, and sown as early as possible in the spring. Seed thus stored through the winter is, however, apt to lose about one-half of its germinative capacity, and even then a good deal of it may fail to germinate until the following spring, in place of the seedlings springing up about five or six weeks after the seeds are sown. If kept stored over a second winter, the seed loses its germinative power entirely.

When one year old, the seedlings should be planted in the nursery-rows, and should remain there two years, at 4 in. distance in rows 15 in. apart. Sycamore stands pruning well, although its recuperative power is not so great as that of the Ash. Young trees pruned in winter or spring, if not well tarred, are apt to bleed profusely, and to be backward in growth for some time afterwards.

Both Sycamore and Maple coppice freely on being cut back to the stool for the first time. The young shoots grow very rapidly, and flush a growth of from 3 to 5 ft. in length during the season. But to maintain its reproductivity in coppice or under woods, it is necessary to fell close to the ground, else the stools soon rot. And after being coppiced once or twice its reproductive capacity becomes weakened, so that it is not really one of the species of trees naturally adapted for permanent coppice under standards.

Sylvicultural Characteristics of Sycamore and Maple.—On fresh good soil Sycamore and Maple can, like most other trees which are not really *shade-enduring* species, stand a considerable degree of over-shadowing before being suppressed as underwood; and in highwoods they can maintain a better leaf-canopy than Oak, Ash, or Elm. But in reality they occupy a sort of position midway between the essentially light-demanding trees and those shade-enduring species capable of also thriving with a less degree of intensity of light,—although this latter class of course also attains its finest development only when in the free enjoyment of light and warmth. In many English plantations on fresh undulating land both kinds of trees are capable of bearing more shade than in the dry Continental climate; but on poor, dry, hilly land the natural demand for light becomes more apparent.

On fresh deep soil Maple and Sycamore can be grown along with Oak, Ash, and Elm in mixed woods with or without the Beech; but on indifferent classes of hilly soil a matrix of Beech suits them best. Sturdy plants may here be introduced on the moister patches of ground, and the Beech may be cut back or thinned out wherever it is interfering with them. They may be advantageously utilised about the sixtieth to eightieth year; but when they have been originally planted in patches, these may be kept until the eightieth to one hundredth year for large timber, unless the soil is likely to deteriorate under them. There is usually so good a natural crop of Sycamore and Maple (and also of Ash) seedlings in mixed woods, that natural regeneration of these is easy if there are no rabbits to devour them.

(2) MAPLE or NORWAY MAPLE, *Acer platanoides* L.

Specific Character.—*Leaves* cordate, smooth, 5-lobed; lobes acuminate, with a few coarse acute teeth. *Flowers* rich yellow; April and May, in stalked corymbs, erect, and, as well as the fruit, smooth. *Fruit* with divaricated wings, brown; ripe in September and October (Loudon).

Distribution.—The Norway Maple, as its name indicates, is a native of Norway, and is, in fact, an inhabitant of all the northern half of Europe up to near the polar limit of tree-growth. But besides being indigenous to that part, it is found also in Germany, in Switzerland, and France, and from the last-named country eastward to the eastern boundary of European Russia. It is a very common tree in all the woods of Russia. It is not indigenous to Britain, but was introduced in 1683. It is now one of our commonest and most hardy trees, and is well deserving of a place in most plantations, both with respect to the value of its timber and to its ornamental effect from an arboricultural point of view.

Description.—The Norway Maple is of nearly as rapid growth as the Sycamore. As a lawn tree it is perhaps unsurpassed. It comes early into leaf, and in autumn its bright-yellow foliage contrasts well with the dark-green and russet tints of other trees. Although resembling the Sycamore in form, it is not so heavy and massive, and is easily distinguishable from a distance by its less formal outline. The leaves (Fig. 9) resemble those of the Plane-tree (hence its botanical name) very much more than those of the Sycamore, in having an entire edge and sharper points. But they differ from those of the Plane-tree, in being opposite and in having seven ribs or main nerves, in place of five in the *P. orientalis* and three in the *P. occidentalis.* Though about the same size as those of the Sycamore, they are of a lighter green, and more transparent in texture. They are not apt to be damaged by insects to anything like the same extent as the foliage

Fig. 9.

Leaf of the Maple (A. platanoides).

of most other trees. The young shoots are greenish at first, but later on become brown, with white spots on the bark. In winter the Maple is easily distinguishable from the Sycamore by the brownish-grey bark not peeling off in flakes, and by its brown-red, large, and prominent buds.

Economic Value.—The Norway Maple is not common enough in Britain to admit of its wood being used so much as Sycamore; but it is equally good, and is suitable for much the same purposes. Although less fine in the grain, it is somewhat closer and heavier, and takes a better polish.

It has a sp. gr. of 0·75 when seasoned, and is thus as heavy as the Ash, and between the Sessile and Pedunculate Oak. Seasoning is necessary before it can safely be floated.

Soil and Situation.—The best soil for the Maple is a well-drained sandy loam, with an admixture of lime; but it thrives on any fresh soil below average quality if it have no tendency to stagnation. It is a tree of the plains and the lower undulating hills; but though it cannot ascend to the same elevations as the Sycamore, yet it thrives farther to the north, where there is less summer warmth. In Norway it grows close to the sea-shore, and stands the sea-blast well. It is therefore remarkable that it has not been more cultivated in this country on estates along our sea-coasts. It does fairly well on the west coast of Scotland, and might sometimes be cultivated with more chance of profit than many other trees.

The Sylvicultural Characteristics of Maple are in general very much like those of the Sycamore, save that it can thrive farther to the north, although it cannot ascend the hillsides to the same elevation. It suffers less than Sycamore from late frosts in April and May, but is not really a hardy species in damp frosty localities. It is not in reality a true shade-enduring species, and it is not naturally fitted for forming pure forests, but can best be grown (like Ash and Elm) either individually or in small patches among Oak and Beech. They may there be cut out about the seventieth year, when the Oak demands a larger amount of growing-space. On good fresh soil the underwood formed by Maples, Ash, Elm, &c., cut out of the highwood crop, is often in our damp climate capable of forming a sufficiency of underwood to safeguard the soil against deterioration; and in this case such hardwoods of course form a more valuable crop than Beech or Hornbeam.

Cultivation.—The Norway Maple is raised from seed in the same way as the Sycamore. It often begins to bear seed about five to ten years earlier than the Sycamore in highwoods, good seed being often gathered from trees of thirty-five to forty years of age; and it produces it even more freely and abundantly. The seed ripens towards the end of September and the beginning of October. Neither sowing nor planting is difficult. If stored over winter the seed is very apt, like that of the Sycamore, to lose greatly in germinative capacity; but as it seeds annually, there is seldom any occasion for storage. When sown in autumn, and at the same time it is not desired that the seedlings should come up too early in spring on account of late frosts, germination may be retarded by giving it a slightly thicker soil-covering than usual.

(3) THE SOFT, SUGAR, or BIRD'S-EYE MAPLE,

Acer saccharinum L.

Specific Character.—*Leaves* cordate, smooth, glaucous beneath, palmately 5-lobed; lobes acuminated, serrately toothed. *Flowers* small, yellowish, in corymbs suspended on long, slender, drooping peduncles; April and May. *Fruit* smooth, with the wings diverging, brown; ripe in September (Loudon).

Distribution.—The Soft Maple is indigenous to North America between the 30th and 50th degrees of latitude. It occurs all over Upper Canada, on most of the richer portions of the lands, where it forms nearly one-third of the natural forests. In Lower Canada it is also plentiful, but not nearly so abundant. It is likewise found in many parts of the Northern States of the Union, especially in New York and Pennsylvania; but only in patches, the natural forests having mostly been cleared away. It was introduced into Britain in 1735.

Description.—The leaves of the Soft Maple resemble those of the Norway Maple, being nearly of the same shape and size; but it is easily known from the latter by the leaves being whitish on the under side in summer, and becoming red (and not yellow) in autumn, while the bark is whitish and not light-brown like the Norway Maple. In the American woods the Soft Maple is usually a large tree of about 90 ft. in height, and from 2 to 4 ft. in diameter, with a clean bole running to a height of 60 or 70 ft., and a diameter of 5 ft. Some even have a total height of over 120 ft. It is this tree that gives the splendid effect to the American woods during the "Indian summer" in September and October, when the foliage assumes all shades of colouring from a bright orange to a dark crimson, and forms a splendid contrast with a background of dark Pine-trees. Though deserving of extensive cultivation in Britain from an ornamental point of view, it can never become one of our woodland trees like Sycamore and Maple.

Economic Value.—Where it is plentiful, the timber is in America used as fuel in preference to any other kind, and it is also employed very extensively for housebuilding and furniture. Considerable quantities of this well-known "**bird's-eye Maple**" are imported from Canada for cabinetmaking. Large quantities of sugar are made from its sap.

Soil and Situation.—It is not so hardy in Britain as the Norway Maple or the Sycamore, and requires a sheltered situation and a good, dry, and rather light soil. It will attain fair dimensions on such land not over 400 ft. above sea-level, when it has the shelter of other plantations, and when planted on the southern sides, or in openings in these; but it will not grow on bleak or exposed parts, nor on a cold-bottomed soil, especially with a northern exposure.

According to experiments made in the State forests of Northern Germany, the Soft Maple thrives best on a fresh, and somewhat loamy, sandy soil. At first it is of slower growth than Maple and Sycamore, but soon becomes more energetic. Like them, it is somewhat sensitive to late frosts in spring, and requires some kind of protection. The wood produced is said to be good, and its cultivation has been recommended on suitable situations. The use of good stout transplants of 3 to 4 ft. in height is recommended.

Another North American species, the Silver Maple (*A. dasycarpum*), also deserves the attention of arboriculturists. It grows quickly, attains good dimensions, is little sensitive to late frosts, and is hardy in exposed windy situations. Its foliage is in itself beautiful, as it throws out many short shoots, which hang around it like a pendulous veil or fringe.

Cultivation.—This tree is usually raised from seed imported from America, which can be dealt with in the nursery in the same way as Sycamore.

SALICACEÆ Rich.

This family, which is almost entirely confined to the northern hemisphere, and chiefly inhabits the temperate zone, contains only the two genera, Willow (*Salix*) and Poplar (*Populus*), distinguished as follows :—

Genus.	Buds enclosed within.	Catkin-scales.	Stamens.	Leaves.	Habit of growth.
Willow	1 apparent bract (but really the 2 lowest joined together)	Entire	2, 3, or 5, seldom more, are prominent, the anthers being supported on long filaments, and instead of the stamens and pistil being enclosed in a cup-like receptaculum, two glands are situated below the ovary (one on each side, one of which usually withers or becomes deformed)	Whole and unlobed, with short petioles	Majority of species merely shrubs, and not trees.
Poplar	Several bracts	Cleft or toothed	8 to 30; they have short filaments, and are, along with the ovary or base of the pistil, surrounded by a cup-shaped receptaculum	Mostly large and broad, or frequently lobed, and with long petioles	All species are trees, and none mere shrubs.

7. THE WILLOW, *Salix* (Linnæan System, Diœcia Diandria).

Generic Character.—*Bractea* to the flower of each sex entire. *Male flower* consisting of 1-5 stamens, more in a few species, and of one or more glands inserted contiguously to the stamens. *Female flower* consisting of a pistil that is stalked or sessile, or nearly sessile, and one or more glands inserted contiguously to it (Loudon).

The Willow is a genus of many species. De Candolle's *Prodromus*, 1868, distinguished 160 species and 68 hybrids, of which 31 species and 57 hybrids were European. But comparatively few of these grow to a size yielding useful timber. Only two true species, the common White Willow (*S. alba*) and the Crack Willow (*S. fragilis*),[1] and one hybrid formed by these two species, the Bedford Willow (*S. Russelliana*), attain, on a favourable soil and situation, the dimensions of timber-trees of the first magnitude. All of these three well deserve the attention of the arboriculturist and the forester.[2] Doubts exist as to either of these true distinct species being indigenous to Britain, and both may have been introduced in

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[1] These two true species of Willow are distinguished as follows :—

1. Leaves covered with silky hairs, and whitish or greyish on the under surface. Male flowers with 2 glands and 2 free stamens; female flowers with 1 gland. *S. alba.*
2. Leaves lanceolate, coarsely serrate and glandular. Branches and twigs easily broken off at the point of junction with the stem, and in mature trees bent upwards. Male flowers with 2 glands and 2 stamens; female flowers also with 2 glands . . . . *S. fragilis.*

[2] As in this portion only trees are being dealt with, no description is here given of **Osiers**. But they are treated of along with other coppice-woods in Part III., *Sylviculture*.

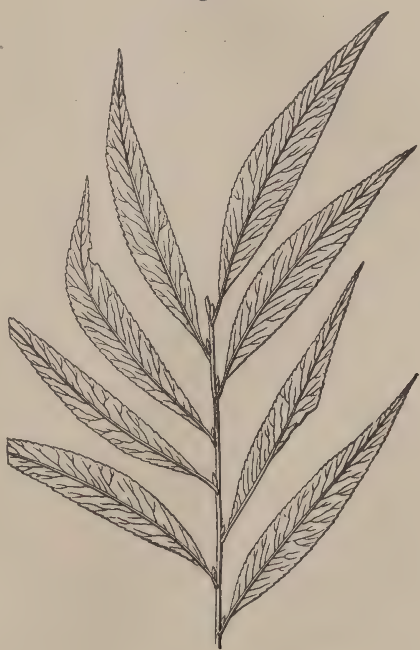
the fifteenth century. The only undoubted native species seems to be the Saugh, Sallow, or Goat Willow (*S. caprea* L.), which, like its hardy relative the Aspen, is found over the whole length and breadth of Europe, and also stretches far eastwards into Asia. The Sallow is common in moist low-lying tracts of woodland, and is easily distinguishable from any of the other species of Willow by its broad oval leaves, pointed and generally twisted at the tip, which are of a smooth dark-green colour above, but covered with greyish down beneath. It is, however, in general only a small tree, and is often a mere shrub on hillsides.

(1) THE COMMON WHITE or HUNTINGDON WILLOW, *Salix alba* L.

Specific Character. — *Leaves* elliptic-lanceolate, pointed, serrated, silky on both sides; the lowest serratures glandular. *Stamens* hairy. *Germen* smooth, almost sessile. *Stigmas* deeply cloven. *Scales* notched. *Flowers* yellow; May (Loudon).

Distribution.—Hooker (*Students' Flora*, p. 337) considers this species native; but even if not truly indigenous to Britain, it has at any rate been growing here since the fifteenth century. It is found in most parts of Europe, from Sweden to the Mediterranean, and also occurs in Western Asia.

Fig. 10.



Foliage and young wood of the White Willow (S. alba) *during month of August.*

Description.—In a favourable situation the White Willow attains large dimensions, and has an agreeable and elegant outline; hence it is worthy of a place in any extensive park or lawn, where the soil is deep, strong, and somewhat moist, and the situation not too exposed. Its growth is very rapid, and it is well suited for planting to hide any disagreeable object.

The leaves of the different kinds of Willows often resemble each other so closely that differences can only be distinguished by careful examination. In the White Willow both sides of the leaf are covered with fine silky hairs lying closely upon the body of the leaf, which give the leaves a whitish appearance when they are slightly moved by wind. This is one of the best of all Willows for **coppicing** or **pollarding**; and where any demand exists for small poles and material of this class, it forms profitable coppices when worked with a low rotation up to about ten or twelve years. The Huntingdon Willow is common all over Britain, and ranges up to 70 ft. high, with a diameter of about 3 ft. at breast-height.

Economic Value.—In general, the wood of all the tree Willows is better than that of Poplars, for it is tougher and more durable. Though soft, it is one of the best woods that can be used wherever toughness combined with light weight is important. It is less liable than Pine or Fir wood to split or get injured, and will last longer than either of these as a paling-rail. It is largely used for the lining of carts and waggons, for packing-cases, &c., and used to be extensively grown for charcoal in powder-making. On the Continent all kinds of Willow-wood are used as the framework for veneered furniture, for packing-cases, and as the raw material for match and wood-pulp factories. The sp. gr. of Willow-wood in general is about 0·85 when green and 0·53 when seasoned; hence it is at once floatable.

Soil and Situation.—The White Willow is accommodating as to soil, so long as this contains the requisite quantity of moisture. But its finest dimensions are attainable on deep loamy or loamy-sandy riverine tracts of a marshy description, such as are found near lakes and rivers, or by the sides of streams running through sheltered glens or ravines. There, if the soil be moderately good, the trees grow rapidly, and attain large dimensions in a short time. But it can thrive fairly well on most soil that is not too light and dry, provided the situation be not too exposed.

Cultivation.—Willows are the easiest of trees to propagate. All that is necessary is to put a slip of young wood into the soil in spring, and in the following autumn it will be ready for transplanting into the open. Pieces of older wood can also be used for cuttings; but slips from the last year's wood make the best plants and the most rapid-growing and finest trees.

In order to have this Willow grow well and produce a good clean bole, it should be planted in a mass, so as to be drawn up quickly; and when this has been effected, thinning may take place to give the young trees more growing-space. This is particularly necessary for the White Willow, which is very liable to throw out large branches if not confined laterally. But where planted somewhat closely together, or if mixed with a few Conifers, it grows high before branching; and when thinning operations are carefully attended to, good timber is produced. The Willow—like the Poplar—should never be pruned except when young. If large branches be taken from a full-grown tree, the wound never heals properly. Unless the wound-surfaces are small and can cicatrise rapidly, the wood soon becomes infected with fungous diseases occasioned by various species of *Polyporus;* for the soft porous wood of Willows and Poplars is little able to resist the penetration of the *hyphæ* and the *mycelium* into the woody tissue when once the fungous spores have lodged on the surface of the wound, and have begun to germinate.

(2) THE CRACK, CRACKING, or REDWOOD WILLOW, *Salix fragilis* L.

SYNONYMS—*S. decipiens* Hoffm.; *S. fragilissima* Host.; *S. monspeliensis* Forb.

Specific Character.—*Leaves* ovate-lanceolate, pointed, serrated throughout, very glabrous. *Footstalks* glandular. *Ovary* ovate, abrupt, nearly sessile, glabrous. *Bracteas* oblong, about equal to the stamens and pistils. *Stigmas* cloven, longer than the style. *Flowers* yellow; April and May (Loudon).

Distribution.—This tree is not indigenous to Britain, but was introduced in the fifteenth century, and is thoroughly acclimatised.

Description.—The Crack Willow is more common in Scotland than in England, where the White and the Bedford Willows are the two chief species of this genus. It is in all respects hardier than either of these two others. In the north of Scotland it is known as the *Redwood Willow*, from the colour of the timber, and is much prized as timber. It is a very quick-growing tree. Its ordinary dimensions are about 50 ft. high and about 2 ft. in diameter; but when planted on a good soil and in a sheltered situation, it can, at about thirty-five years of age, attain 70 ft. in height, and 8 ft. in girth at 4 ft. from the ground. The leaves (Fig. 11) resemble those of the White Willow, being slightly downy when young. It is not one of the best of trees for lawns and parks, being apt to become "stag-headed" if grown on unsuitable soil; otherwise it is quite as ornamental as the White Willow.

Fig. 11.

Foliage of the Crack Willow (S. fragilis).

Economic Value.—The Wood of the Crack Willow is tougher and more durable than that of either of the other two tree Willows. It is good for interior work and flooring, as it is extremely light, and lasts a long time. It is specially suited for the construction of railway waggons and trucks, and picked wood fetches a high price for cricket-bats.

Soil and Situation.—The Crack Willow will attain fair dimensions on a greater variety of soil than either the White or the Bedford Willow, but it requires a deep and rather moist soil and a sheltered situation to grow quickly into large size.

Cultivation.—Like the other Willows, it is easy of propagation by slips or cuttings in the same manner as already described for White Willow.

(3) RUSSELL or BEDFORD WILLOW, *Salix Russelliana* Forb.

SYNONYM—*Salix fragilis var. Russelliana* Hooker.

Specific Character. — *Leaves* lanceolate, tapering at each end, serrated throughout, very glabrous. *Footstalks* glandular or leafy. *Ovary* tapering, stalked, longer than the bracteas. *Style* as long as the stigmas. *Flowers* yellowish ; April and May (Loudon).

Distribution.—Though not originally indigenous, this tree is in one sense a native, for it is merely a hybrid of the White and the Crack Willows. It is found in most marshy woods and osier-grounds throughout England.

Description.—The Bedford Willow is well worthy of a place in pleasure-grounds. In lawns or parks it produces a better effect than any other Willow, as it has a bold outline and rather a rugged habit, which gives it, when seen from a distance, more the look of an Ash than that of a Willow. The Bedford Willow may be easily distinguished from the White Willow by its lanceolated, tapering, and serrated leaves, which are hairless and smooth on both sides, and are larger than those of the latter (see Fig. 12).

Fig. 12.

Twig and foliage of the Russell or Bedford Willow (S. Russelliana), *in month of August.*

Economic Uses of Timber.—The timber is used for much the same purposes as the White Willow, and there is very little difference in the quality of the two kinds of wood.

Soil and Situation.—What has already been said with regard to the White Willow is applicable to this species. Under similar circumstances, they attain about the same dimensions. When planted on an exposed situation, the branches of the Bedford Willow are very apt to be broken by high wind, a tendency which it naturally inherits from the Crack Willow. But in other respects it is somewhat hardier than White Willow.

Cultivation.—As with the White Willow.

8. THE POPLAR, *Populus* (LINNÆAN SYSTEM, DIŒCIA OCTANDRIA).

Generic Character.—*Bractea* to the flower of each sex laciniated on its terminal edge. *Male flower* consisting of a calyx, and 8 stamens at fewest, in many instances many more. *Female flower* consisting of a calyx and a pistil (Loudon).

Several species of this genus are well adapted for forest-trees. About twenty kinds of Poplar are enumerated in the last edition of De Candolle's *Prodromus*, but only seven are of arboricultural or sylvicultural interest in Britain, and only one is indigenous, the Aspen. The species most worthy of notice are the Black Poplar (*Populus nigra*), the Abele or White Poplar (*Populus alba*), the Grey Poplar (*P. canescens*), the Lombardy Poplar (*P. pyramidalis*), the Canadian or Black Italian Poplar (*P. canadensis*), the Ontario Poplar (*P. candicans*), and the Aspen or Trembling Poplar (*P. tremula*).

These seven species of Poplar are distinguished as follows (Willkomm) :—

I. **Black Poplars.**—Leaves with translucent edges, coloured nearly alike on both surfaces, and never lobed.

1. Crown broom-shaped, consisting of very numerous long shoots and but few short shoots ; long shoots when young without corky bark ; ovary oval and consisting of two divisions ; stigma divided. **Black Poplar.** *P. nigra.*
2. Crown diffuse, consisting of comparatively few long shoots and very numerous short shoots ; long shoots of no great length when young, but thick, and ribbed with corky bark ; ovary pumpkin-like, with 3 or 4 divisions, often having depressions between them ; stigma simple. **Canadian Poplar** . . . . *P. canadensis.*
3. Crown consisting of upright branches, narrow, and conical in outline. **Lombardy Poplar** . . . . *P. pyramidalis.*

II. **Aspens.**—Leaves mostly wavy-edged, or coarsely toothed, and occasionally lobed.

4. Leaves with snow-white pubescence or felty down on the lower side, and of two different shapes, those that are formed first on shoots of young growth being round and somewhat wavy-edged, whilst those formed later on older shoots are much larger, and have 5 more or less distinct lobes ; stigma dividing into 2 ends. **White Poplar** . . . . . . *P. alba.*
5. Leaves with greyish-white pubescence on the lower side, and always of the same shape ; stigma dividing into 4 ends. **Grey Poplar** . *P. canescens.*
6. Leaves of the short shoots nearly round, and with bluntly notched or toothed edges ; stipules linear-lanceolate. **Aspen** . . *P. tremula.*

III. **Balsam Poplars.**—Leaves green to the extreme edge of the upper surface, but of a whitish-green colour on the lower side, and never lobed. Crown diffuse, as there are few long, but many short shoots.

7. Leaves triangularly or ovally cordate, and almost as broad as long (resembling the leaf of the Lime in shape). **Ontario Poplar** *P. candicans.*

(1) THE COMMON BLACK POPLAR, *Populus nigra* L.

SYNONYMS—*P. viminea* Du Ham. ; *P. vistulensis et polonica* Hort.

Specific Character.—*Petiole* somewhat compressed. Disk of leaf deltoid pointed, serrated with glanded teeth, glabrous on both surfaces. *Catkins* lax, cylindrical. *Stigmas* 4, simple, spreading. *Flowers* dark-red ; March and April. *Seed* ripe in May (Loudon).

Distribution.—Although Black Poplar is now to be found throughout the greater part of Europe and in some parts of the north of Africa, it is really indigenous only to the southern parts bordering on the Mediterranean Sea. It is of true forest growth only in the low-lying tracts throughout Spain, Southern France, Italy, Austria, Roumania, and Greece, whence it stretches eastwards into Southern Siberia. It was probably introduced into Britain by the Romans.

Description.—In each of the three main classes of Poplars many of the species much resemble one another in their leaves. But the Black Poplar is easily distinguishable from most of the others by its pale-green and shining leaves (Fig. 13). The leaf-stalks are thin and slender at their insertion upon the leaf, which causes a vibrating motion with every breath of wind.

The name "**Black Poplar**" has reference to the bark, which soon fissures longitudinally and (in contrast to the White Poplar and Aspen) loses its smooth, light surface. The colour deepens as the stems increase in age. It is easily recognisable at a distance from its nearest relative, the Canadian or Black Italian Poplar, by the crown being somewhat thinner and more open, owing to the branches leaving the stem at a wide angle; whilst in the latter they form a smaller angle with the stem, and also curve in slightly near their extremities. It soon grows into large timber, and it is fully mature at about fifty years of age. When planted in a low-lying moist situation, even without having the advantage of shelter, it forms a very graceful and prominent object in the landscape; but if planted among trees of slow growth it soon overtops all the others, and then has by no means a fine arboricultural effect. In a situation suited to it, it forms an extremely massive trunk and a large spreading top. It is the quickest-growing of all the European species of timber-trees, and at thirty years of age may reach a height of about 80 ft., and contain upwards of 60 cubic ft. of timber.[1] It is therefore a very profitable tree when planted on a suitable soil and site.

Fig. 13.

Leaf of the Common Black Poplar (P. nigra).

Economic Value.—The wood of this tree is much used for railway waggons, cart-making, and turnery. It is soft and light, hence suitable for packing-cases or similar articles where lightness is of more consideration than durability. Good trees fetch easily from 6d. per cubic foot upwards.

Soil and Situation.—It should be planted in a good, deep, strong, and moist loam, but not with stagnant water in the subsoil; for although the tree often attains a large size in damp and temporarily water-logged spots, yet it will not (nor will any other Poplar) thrive if its roots reach permanent stagnant water; nor will this, or any other Poplar, do well upon high, dry, thin soil. Black Poplar thrives best upon a deep sandy loam, and in a sheltered situation among other trees where it has ample room to spread out its

[1] Mr Elwes, Colesborne Park, Gloucestershire, says (*Transactions of Surveyors' Institution* for 1904, p. 226): "I lately felled 30 Black Poplars not over forty-eight to fifty years old, which averaged about 120 cubic ft., and made £3 each standing, though ten miles from the yard where they went for conversion into railway-brake blocks. What other tree will do this on land rated at 5s. per acre?"

branches. Trees of very large size may also be grown upon a poor light soil, situated upon sloping banks, where water percolates freely down the slope.

Cultivation.—This species is generally propagated by slips or cuttings of the young wood (Fig. 14), which easily take root in the nursery. After remaining one year as cuttings, they are fit for planting out into the open.

Fig. 14.

Slip or cutting of the Black Poplar, as prepared for "setting" in the nursery.

(2) CANADIAN or BLACK ITALIAN POPLAR,

Populus canadensis Desf.

SYNONYMS—*P. monilifera* Ait.; *P. virginiana* Dum.; *P. marylandica* Bosc.; *P. lævigata* W.; *P. carolinensis* Mönch.

Specific Character.[1]—*Petiole* compressed. Disk of leaf roundish-ovate, deltoid, acuminate, subcordate at the base, where there are glands, serrated with unequal teeth, glabrous. The *branches* are angular, and the angles form whitish lines, which persist even in the adult age of the tree. The young *buds* are gummy. *Flowers* red; April and May. *Seeds* ripe in June (Loudon).

Distribution.—This species is a native of Canada and the United States, where it is generally found growing in ravines and on strong clay land along with other Poplars, and forming trees of from 60 to 70 ft. in height, with a stem of from 18 to 24 in. in diameter near the ground. It was introduced into Britain in 1769.

Description.—Like the other Black Poplars, this species is characterised by more rapid growth than any of the Aspens or Balsam Poplars, stems here growing to 100 ft. in height and 3 to 5 ft. in diameter, or considerably larger than in its native locality. In habit it resembles the Common Black Poplar; but its crown of foliage is somewhat thicker, the branches are more upright, and the tips of the twigs bend in slightly towards the stem—distinctions that may often be recognised from some distance. The leaves are usually larger and of a darker green than the foliage of the Black Poplar; but these differences are comparatively slight and inconstant. It grows well in the London parks, in spite of the smoky atmosphere, but soon turns ragged in foliage and rather unsightly.

Economic Value.—The timber is very similar, and perhaps somewhat superior, to Black Poplar, and is used for the like purposes. It is generally of larger dimensions than any other of the Poplars; but as regards durability and general quality of the timber, there cannot be said to be much difference between it and the wood of the Black Poplar. None of the tribe can, how-

[1] When short stiff hairs can be detected with a magnifying-glass between the teeth at the edge of the leaf, the tree is of the variety known throughout the United States as the Cottonwood (*P. monilifera*). This species has been found to grow quickly in Germany on any sort of soil, including even poor sand, although it does best on moist, marshy land.

ever, compare with it in the great length of stem available for timber; for in this respect it often even surpasses the Black Poplar, which is usually the most rapid-growing and most productive of all our timber-trees.

In the State forests of Northern Germany this species is more largely cultivated than any other exotic Poplar. Besides standing the trying Continental climate well, it shows itself accommodating as to soil, and extremely rapid in growth; whilst its wood is considered to be of better quality than that of the Black Poplar. And although essentially a *light-demanding* species of tree, its more restricted crown gives it a sylvicultural advantage over the latter.

Being very hardy as regards frost, it thrives well in the far North. In Norway it now receives great attention on account of its rapid production of light timber suitable for match-making, paper-pulp manufacture, &c.

Soil and Situation.—The Canadian Poplar requires a strong loamy soil and a sheltered situation. When planted on an indifferent soil, or on any site much exposed to wind, it is inferior to the Common Black Poplar, both with regard to the quantity and the quality of its wood. As a timber-tree it is therefore only suited for land of good quality; but on such it may often attain extraordinary dimensions, even when comparatively young.

Cultivation.—It is usually grown from slips or cuttings of the young wood, which root freely in any moderately light land. Cuttings of one year's growth are not infrequently fully 4 ft. high, and are quite fit to plant out into the woods.

(3) THE ITALIAN or LOMBARDY POPLAR,

Populus pyramidalis Roz.

SYNONYMS—*P. dilatata* Ait.; *P. fastigiata* Pers.; *P. italica* Mönch.

Specific Character.—*Leaves* in the bud involutely folded. A fastigiate tree. *Petiole* compressed. Disk of leaf deltoid, wider than long, crenulated in the whole of the edge, even the base; glabrous upon both surfaces. *Flowers* red; March and April.

Although it has been classed as a separate species in De Candolle's *Prodromus*, some botanists consider this merely a variety of the Black Poplar.

Apart from its peculiarly fastigiate growth, and its long, conical crown, formed by the thin branches striving strongly upwards, it exhibits no botanical differences from the Black Poplar. In their wild state, trees producing female flowers have only been found on the Himalaya Mountains (by Royle) and throughout the northern part of the Punjab (by various forest officers), although some occur cultivated in Southern Germany and in Austria. All the trees of this species throughout Britain are of the male gender. But as propagation can be very easily effected by means of *slips* or *layers*, this want of natural regenerative power is practically of no consequence arboriculturally.

Distribution.—As its name indicates, this tree is a native of Lombardy, and is found on the banks of the Po. It was introduced into Britain about 1758.

Description.—Its narrow, fastigiate form and the entire absence of horizontal branches give it a distinctive habit much resembling that of the Irish Yew. It is a tree only suitable for arboricultural purposes, as in avenues or parks, where its tall and upright form has an imposing effect among trees of low, spreading habit. Throughout France, Germany, Denmark, Holland, and Belgium it is one of the kinds of trees most frequently to be found forming avenues along roadsides. But it throws long shadows over crops lying behind it, and, like the Ash, its long, shallow, straggling surface-roots absorb large food-supplies from the soil. This tree becomes depressingly monotonous along mile after mile of public highways.

Economic Value.—As the stem is generally deeply furrowed, and seldom of large diameter, it is not valuable as timber. In England it often attains a height of 100 ft. at about fifty years of age. It can only be used where lightness is more important than durability, and it ranks lower in quality than the timber of either the Black or the White Poplar.

Soil and Situation.—From Ebermayer's investigations it has been shown that the Italian Poplar makes demands for mineral nutrients exceeded only by those of the Ash; and at the same time it seems able to transpire larger quantities of water per unit of dry substance of its foliage than any other species of woodland tree. It requires a strong loamy soil and good natural shelter. Without these it grows comparatively slowly, and becomes merely a tall, densely branched bush. It is well adapted for street-planting in towns, as it takes up but little space with its closely-drawn-up branches, and is less affected by smoke than many other kinds of trees. When planted closely in a line, it forms an excellent tall hedge, and quickly provides shelter.

Cultivation.—This tree is propagated chiefly by slips or cuttings of the young wood, which in light open soil root freely, and are fit to plant out when one or two years old, according to the height of plants wanted.

(4) THE ABELE-TREE or WHITE POPLAR, *Populus alba* L.

Specific Character.—*Leaves* lobed and toothed; somewhat heart-shaped at the base; snow-white, and densely downy beneath. *Catkins* of the female plant ovate. *Stigmas*, 4. *Flowers* dark-brown; March. *Seed* ripe in May (Loudon).

Distribution.—The White Poplar is indigenous to Southern Europe, the west of Asia, and the north of Africa. It has been long in cultivation in Britain, and was probably introduced along with the Black Poplar at a very early date. For climatic reasons, it is extremely improbable that it is indigenous to Britain, as some have held. It is grown to a considerable extent throughout France and Germany. In some of the French forests it is now the chief tree for supplying the local demands for fuel.

Description.—This tree has an upright habit, and its white, waving, downy leaves and silvery branches contrast well with other foliage of a darker colour. On favourable soil and situation it grows to a height of from 70 to 100 ft., with a bole from 2½ to 5 ft. in diameter. The leaves of young plants are larger and much more strongly lobed than those of older trees (Figs. 15 and 16). When young, they are covered with a white down beneath, and on the upper surface but slightly. In plants a few years old the leaves are much smaller, though also dark-green and smooth on the upper surface; and they are not so strongly lobed. The young branches (Fig. 17) are thickly covered with down, and are of a more spreading and ramifying habit than those of the Canadian Poplar; and they are also tougher and more slender. Wherever it is planted, this tree throws out shallow surface-roots and sends up large quantities of suckers all round, which often become troublesome on pasture. Hence it should not be planted on grazing land, but confined strictly to the woodlands.

Economic Value.—The wood is white, very light, and spongy, but as durable as that of the Common Black Poplar. It is suited for floor-planking, cart and waggon bottoms, packing-cases, turnery, and cabinet-work; and the boards and rollers round which manufactured silk is wrapped are for the most part made of it, as it is soft, light, and not liable to injure the silk. It has a sp. gr. of 0·95 when green and 0·48 after seasoning. Along with Aspen and Black Poplar, it is worth cultivating wherever its wood may be disposed of to local match factories or cellulose mills, or any similar industry requiring a regular supply of soft timber. It resembles the Black Poplar in yielding marketable timber of good size at about forty to fifty years of age.

Fig. 15.

Leaf produced on a two-year-old coppice-shoot of the White Poplar (P. alba).

Fig. 16.

Leaf produced on an older shoot of the White Poplar.

Soil and Situation.—Like the Common Black Poplar, the White Poplar thrives best in a sheltered situation and upon a moist and loamy but not a binding soil. When planted on low-lying ground near the sides of streams, where the soil is deep and open, it grows rapidly, and in a few years attains large dimensions. Where it grows spontaneously near the banks of streams, the soil will generally be found to be of a sandy-loamy or humose description. Although not so exacting with respect to the amount of mineral food extracted from the soil, it is less accommodative than the Black Poplar to land that is not exactly of the loamy-sandy description that suits it best; and on the whole it is not so rapid in growth as that species. On heavy argillaceous soils it is apt to become "stag-headed." It coppices well, and on favourable soil quickly produces a crop. It can thrive near towns, and is not so much affected by the smoke as many other trees are.

Fig. 17.

Branchlet of the White Poplar.

Cultivation.—It can easily be raised from slips or cuttings, layers, and root-suckers, though the slips or cuttings do not, however, strike so readily as those of the Black Poplar; but this method is easy, cheap, and satisfactory. Suckers spring freely from the roots. If put into the nursery in spring, they are ready for planting into the open during the following autumn or spring; but spring planting is preferable.

(5) THE COMMON GREY POPLAR, *Populus canescens* Sm.

SYNONYMS—*P. alba aut canescens* Ait.; *P. alba-tremula* Wimm.

Specific Character.—*Leaves* roundish, deeply waved, toothed; hoary and downy beneath. *Catkins* of the female plant cylindrical. *Stigmas* 8. It is distinguished from *P. alba* by the stigmas, which are 8, spreading in two opposite directions. The *bracteas* of the fertile flowers are also more deeply and regularly cut (Loudon).

Distribution.—The Grey Poplar is a native of Northern Germany, lower Austria, and Servia, whence it was introduced into North-western Europe. Although able to produce seed in a specific manner, it is now by many botanists regarded as a hybrid between *P. alba* and *P. tremula*.

Description.—The greyish-white, pubescent foliage of the young Grey Poplar somewhat resembles that of the White Poplar; but later on it is more like that of the Aspen,—a similarity that is heightened by its flattened leaf-stalk, in which respect it differs essentially from the former species. In its general characteristics, however, it has a much greater resemblance to the White Poplar than to the Aspen. It has a greater propensity than the White Poplar to send up suckers, often at a great distance from the tree, and the branches are more upright and compact. It can at once be distinguished from White Poplar by its leaves being less deeply lobed, and by the down being somewhat grey upon the under side of the leaf (Fig. 18). In favourable situations it grows as rapidly, and to as great a size, as the White Poplar, but its branches assume a more upright form of growth.

Fig. 18.

Leaf of the Grey Poplar (P. canescens).

Economic Value.—The wood is used for the same purposes as that of the White Poplar.

Soil and Situation.—The Grey Poplar grows best on a good moist loam, and of course the more sheltered the situation the more rapid will its growth be. It is a very hardy and accommodating species, and attains the dimensions of a timber-tree on a greater variety of soils and situations than any other of the Poplar genus.

Cultivation.—The Grey Poplar is grown in the same way as the White Poplar, though less frequently from slips or cuttings than from suckers. Suckers continue longer in healthy growth, and therefore usually deserve the preference. When detached from the roots of the parent tree, they may be put into nursery-rows for one year, when they will be ready for planting. As, however, suckers cannot always be got, nurserymen generally propagate trees by layers from stocks (in the same way as the English Elm). It coppices well, producing a good flush of shoots even on indifferent soil, and the root-suckers it also throws up help to thicken the crop.

(6) ASPEN or TREMBLING POPLAR, *Populus tremula* L.

Specific Character.—Young *branchlets* hairy. *Leaves* having compressed footstalks, and disks that are roundish-ovate, or nearly orbicular; toothed in a repand manner, downy when young, afterwards glabrous on both surfaces. *Stigmas* 4, erect, eared at the base. *Flowers* brown; March and April. *Seeds* ripe in May (Loudon).

Distribution.—The Aspen is one of the comparatively few trees truly indigenous to Britain, and is found in most parts of the United Kingdom. It is common in the cold, wet districts of the Scottish Highlands, and is also plentiful in the Spey valley, and on Deeside as far up as Braemar. It is not, however, a common tree in Ireland. It has probably a larger range than any other species of tree, as it occurs from Lapland southwards into Africa, and from Ireland and Portugal eastwards through most of Asia, even to Japan. Although its exact limits have not yet been determined, its range embraces no less than 35° of latitude and 140° of longitude. In Eastern Prussia, Poland, Western Russia, Galicia, and Hungary it forms extensive forests throughout low-lying tracts, where it is often to be found forming pure woods, although more generally mixed with the Birch and the Common Alder. In other parts of Europe it is chiefly to be found in clumps or patches of various extent scattered throughout the woodlands, and generally occupying low, moist tracts. Its finest growth is attained in Poland, and throughout the neighbouring parts of Prussia and Russia (Willkomm).

Description.—The leaves of all the Poplars are easily put in motion by a gentle breeze, but those of the Aspen often become agitated while no breeze is felt; and few woodland phenomena are more attractive than the fluttering of the Trembling Poplar on a calm evening. This is due to the leaf-stalk being flattened or compressed and set on edge, so that the leaf is always in a sort of unstable equilibrium. The Aspen is a rapid-growing tree, but it attains maturity at an early age, and seldom produces timber of any large size. The smooth grey-barked trunk is generally straight, clean, and tall in proportion to its diameter. The branches extend horizontally, and are for the most part thinly distributed along the stem; hence the tree assumes a drooping habit as it grows old. It has a strong tendency to throw up root-suckers, which are often produced in great profusion near the parent tree. The leaves very much resemble those of the Grey Poplar; but they are distinguishable by being more nearly round, and smooth on both sides after the month of June (Fig. 19). The leaves of stool-shoots and root-suckers are much larger, more pubescent, and more triangular in shape than those produced on seedlings. Under ordinary circumstances the Aspen attains a height of 40 to 50 ft. and a diameter of 12 to 15 in., while under specially favourable circumstances it may reach 70 to 80 ft. in height and 3 ft. in diameter.

Economic Value.—Although the Trembling Poplar is highly ornamental in a park, yet it is of little importance as a timber-tree, for it does not produce timber of nearly so good a quality as either the Black or the Canadian Poplar. The wood is short-grained and brittle. It has a mean sp. gr. of only 0·81 when green and 0·51 after seasoning, and is therefore easily floatable immediately after felling. On the Continent its chief use is for match-making and wood-pulp for paper, along with other softwoods; but Aspen and Lime are preferred to Birch for pulp-making.

Soil and Situation.—Being a very hardy species of tree, it is to be found growing spontaneously in damp localities where late and early frosts are frequent. It is exceedingly accommodating with respect to the mineral character of the soil, thrives on any sort of moist land, and ascends to higher elevations than any of the other Poplars. But whenever planting for profit is under consideration, Aspen can only be expected to yield good returns on fairly good soil; and in the majority of cases the land may be very much better utilised for the growth of other species of trees. On low-lying, well-sheltered meadows, or along the edges of plantations where the soil is moist and deep, it attains its largest dimensions, and often yields as much as 40 cubic ft. of timber per stem.

Fig. 19.

Aspen leaf (P. tremula).

Cultivation.—The Aspen is propagated chiefly from layers and suckers, the latter being plentiful in every wood where the tree occurs. These have only to be dug up with their roots and transplanted into nursery-rows for a year or two, when they are fit for planting.

Sylvicultural Characteristics of Aspen.—The Aspen is not, on the whole, well suited for growth in highwoods along with other broad-leaved trees. Being of more rapid growth at first, it is apt to hinder the development of other species; and although it may then be cut out, yet when once its shallow, far-spreading roots have obtained a good hold on the soil, they long remain capable of sending out quick-growing suckers that are hard to suppress. It is remarkable how suckers spring up when mature crops of timber are cleared away, long after all Aspen-trees have been felled and the stumps have rotted away. This is the great drawback to its use as a nurse for less hardy species in low, damp localities exposed to danger from late frosts in spring,—a drawback that is to a certain extent also chargeable against the Birch. And in moist tracts of coniferous woods, where it is often to be found growing abundantly, its presence is not always desirable. Its foliage is liable to a trifling disease occasioned by the fungus *Melampsora pinitorqua*, which stands in alternate generation with the more serious fungous disease on Scots Pine caused by *Cæoma pinetorquum*, which occasions deformities of the leading-shoots and ultimately of the bole; while another fungus stands in alternate generation with a disease of Larch foliage, caused by *Cæoma Laricis*. In a great many cases, therefore, Aspen is in reality more or less of a weed, and one that it is exceedingly hard to get rid of, owing to its strong reproductive capacity. Its demands for light are only slightly inferior to those of the Larch and the Birch, and if allowed an opportunity of developing its crown, it soon exhibits its natural demand for a large growing-space. Hence, although easily suppressed by other trees, it interferes greatly with their growth if once it be allowed to get its crown free above them.

A humid atmosphere and a moist soil are alike favourable to its development. As its seed-production is large when male and female trees are standing in close proximity to each other, and as the seeds are light and have cotton-like filaments attached to them, they can easily be wafted far into neighbouring woodlands.

In well-managed woods it is only a very minor species of tree, which should be cut out before it has passed the age of forty years; for even by that time its bole has often begun to be unsound. Its sylvicultural treatment corresponds very closely with that of the Birch, with this difference, that when only one of these two kinds of softwoods can be removed at any given time during any of the periodical operations of weeding or cleaning, the Birch usually deserves to be retained as being probably the more valuable ultimately.

Where once the Aspen has been introduced into woods, there will seldom be any necessity for regenerating it artificially; the forester will more often find difficulty in preventing it from becoming a troublesome weed.

(7) THE ONTARIO POPLAR, *Populus candicans* Ait.

SYNONYMS—*P. macrophylla* Lindl.; *P. latifolia* Mönch.; *P. cordata* Lodd.; *P. ontariensis* Desf.

Specific Character.—*Shoot* round. *Bud* very gummy. *Stipules* gummy. *Petiole* compressed in its upper part, hairy in many instances. Disk of leaf heart-shaped at the base, ovate, acuminate; serrated with blunt unequal teeth; 3-nerved; deep-green on the upper surface, whitish on the under one, on which the veins appear reticulate. *Flowers* purplish; March (Loudon).

Distribution.—This species is a native of Canada and the Western States of North America, and was introduced into Britain in 1772. Even in America it is seldom found growing spontaneously, although it is often planted about farm-steadings or along the sides of the streets in towns.

Description.—The Ontario Poplar is of extremely rapid growth, sometimes reaching a height of 50 ft. in fourteen years. It appears to be specially suitable as a timber-tree on shallow soil along the sides of streams. It is distinguishable from the other Poplars by its gummy or resinous buds, which, especially in the spring, have an agreeable balsamic smell, and by its large, more or less heart-shaped leaves, which are generally 6 to 8, and sometimes 10 in. in length, and are of a beautiful deep-green colour on their upper surface. In respect of its buds, it resembles its close relative the Common Balsam Poplar (*P. balsamifera* L.), which is also a native of the same localities, and is often to be found in Britain in parks and public gardens. But the leaves of the Ontario Poplar are much larger than those of the Balsam Poplar.

Soil and Situation.—The Ontario Poplar requires a plentiful supply of soil-moisture, without which it will not thrive. It should be planted along river-banks or on land only 2 or 3 ft. above the level of a stream ; and in such places it will attain large dimensions in a very short time. It is not so hardy as the Canadian Poplar with regard to frost, and this danger is heightened by the fact that it begins to flush its foliage rather earlier in the spring than the latter species. Otherwise it is often of extremely rapid growth, and under favourable circumstances can send out shoots of over $7\frac{1}{2}$ ft. in length during the course of the year ; but as such shoots do not harden thoroughly before autumn, they are apt to be injured by frost.

Cultivation.—This species is readily propagated by slips or cuttings, which grow rapidly and are fit to plant out when they are one or two years old, according as the plants may be wanted of a small or large size. Like the White Poplar, it has a strong tendency to throw up root-suckers around the parent stem ; hence it is not a suitable kind of tree to plant on pasture-land, for its reproductive capacity in this respect is strong, and the stoles are difficult to suppress and get rid of. Similar trouble may also be experienced in nurseries where cuttings of this species may have been allowed to leave portions of their roots behind in the soil when the rooted slips have been removed.

BETULACEÆ Bartl.

The family of the *Betulaceæ* consists of the two genera, Birch (*Betula*) and Alder (*Alnus*), the majority of the species of which inhabit the temperate zone of the northern hemisphere. They are thus distinguished (Willkomm):—

Buds sessile, and enclosed by several bracts arranged spirally ; male catkins mostly in clusters at the top of the previous year's shoots ; female spikes only appearing simultaneously with the foliage, and situated at the end of the short shoots consisting of but a few leaves. Under each bract of the catkin 2 or 3 flowers with 4 stamens, each of which is situated at the corner of a thin leaflet ; anthers divided into two halves ; under each of the 3-lobed bracts of the spike there are 3 ovaries, which produce a broad-winged nut. The cylindrical, petiolated, and pendulous catkins fall to pieces on ripening, leaving only the spindle. Flowering takes place after the flushing of the foliage. **Birch** . . . . *Betula.*

Buds petiolated or stalked (except in the Alpine Alder, *A. viridis*, where they are sessile), and covered with 2 or 3 thick bracts. Male and female flowers on one branching stalk, on the upper part of which the catkins are situated, and on the lower part the spikes. Under each catkin-scale 3 distinctly separate flowers with 4 stamens and floral bracts crosswise ; under each bract of the spike only two ovaries, from which unwinged (except in *A. viridis*), compressed, and angular nuts are produced. The spikes develop into long cones with thick woody bracts, which are at first cemented together with a kind of waxy resin, but which on ripening open and let the seed escape, without falling to pieces and detaching themselves from the spindle. The empty cones remain long on the tree. The flowering (except in *A. viridis*) takes place long before the foliage flushes in spring. **Alder** . . . . *Alnus.*

9. THE BIRCH, *Betula* (Linnæan System, Monœcia Polyandria).

Generic Character.—*Barren flowers: Catkins* cylindrical, lax, imbricated all round with ternate concave scales, the middle one largest, ovate. *Corolla* none. *Filaments* 10 to 12, shorter than the middle scale, to which they are attached. Anthers roundish, 2-lobed. *Fertile flowers: Catkins* similar but more dense; scales horizontal, peltate, dilated outwards, 3-lobed, 3-flowered. *Corolla* none. *Germen* compressed. *Styles* 2. *Stigma* simple. *Nut* oblong, deciduous winged at each side. Flowers whitish, in pendulous catkins (Loudon).

Out of a total of 37 species of Birch, 8 are indigenous to Europe. Of the latter, 5 are to be found in the central and north-western portions of the Continent, including Britain; but as they gradually merge into each other, it is impossible to determine any hard-and-fast lines of distribution for the various species.

Only one species has any value as a forest-tree, the Common Birch, *Betula alba* L., subdivided by Ehrhart into (1) the warty Birch, *B. verrucosa*, and (2) the downy Birch, *B. pubescens*. But the more comprehensive specific name of Linnæus may here be retained, as the sub-species exhibit only comparatively unimportant sylvicultural differences. The warty kind extends farther to the north and east, whilst the pubescent goes farther south. The latter is the Birch most frequently to be found on wet, low-lying soil, and the former prevails on drier situations, though both are often found growing together. The warty kind is the more frequent in the Highlands of Scotland.

There are two ornamental exotic species (*B. lutea* and *B. papyracea*), which were introduced into Britain from North America about the middle of last century. The three species worth describing here are thus distinguishable (Willkomm):—

I. Outer layer of the bark of the stems white.
  1. Leaves rhomboidal or ovate and long-pointed, entire at the base, but doubly, and often trebly, serrate along the upper edges; more or less pubescent on young shoots, but not on any of the foliage of the older twigs (*B. pubescens* and *B. verrucosa*, Ehrh.) **The Common Birch** . . . . . *B. alba.*
  2. Leaves large, ovate, and shortly pointed; entire at the lower edge, but doubly serrate along the upper edges. **The Paper Birch** . . . *B. papyracea.*

II. Outer layer of the bark of the stems brown or brownish-yellow.
  3. Leaves large, ovate, and pointed. Young shoots pubescent and without waxy warts. **The Tall Birch** . . . . *B. lutea.*

(1) THE COMMON or SILVER BIRCH, *Betula alba* L.

Synonyms—*B. pubescens et B. verrucosa* Ehrh.

Specific Character.—*Leaves* ovate, acute, somewhat deltoid, unequally serrated, nearly glabrous. *Flowers* whitish; in England, in February and March. *Fruit* brown; ripe in September and October (Loudon).

Distribution.—The Birch is indigenous to most of Europe, and is specially characteristic of northern and mountainous tracts. In the extreme north of Europe it occurs only as a small tree or large bush; while in the central portion, particularly in Eastern Prussia and Western Russia, it forms extensive forests along with Alder and Aspen, and develops into a tree often attaining a height of 50 to 60 ft. It is indigenous to Britain, and forms sparse natural woodlands in Perthshire.

Description.—Though its foliage is rather small, yet the Birch is one of the most graceful of our trees, and lends itself well to landscape gardening, being especially effective near the edge of a lake or by the side of a stream.

Here it often assumes a pendulous habit in the branches, and is then known as the "Weeping Birch." The largest trees have a height of about 50 ft., and are from 2 to 3 ft. in diameter. In spring the foliage has a sweet smell after a shower of rain.

Economic Value.—The wood of the birch has a sp. gr. of 0·96 when green and 0·65 when seasoned, so that it cannot be trusted to float well just after felling. It is a softwood, not very durable, used by cartwrights, turners, carvers, and cabinetmakers; and blocks with gnarled excrescences ("burrs") command a good price for furniture. For outdoor use, as posts or fences, &c., it does not last more than about three years. In respect of durability, it ranks on about the same level as Beech; and it further resembles this in having good heating power when used as fuel in closed stoves. Even when used for furniture, often of fine lustre and marking, it is apt to be affected by dry-rot. It is much used for making herring-barrel staves, and as charcoal for gunpowder. In parts of the Scottish Highlands the most important use of the Birch is for making *bobbins* for thread-mills, even branches down to 1 in. diameter being serviceable. Throughout the whole of Strath Tummel (Perthshire) the Birch grows luxuriantly, although no attempt seems made to manage the woods on business principles.

Soil and Situation.—Though not to be compared with Oak or Sycamore as to longevity, Birch lives to a great age on a good dry soil suited to its requirements. Far from being particular as regards soil and situation, it is one of our very hardiest trees. It is to be found growing on the poorest sand, and it forms one of the most characteristic trees on the bare hillsides of the Scottish Highlands, existing even in these mountainous districts at an elevation of fully 3000 ft. above the sea-level. Yet notwithstanding this hardiness, it only attains a large size if planted on fair soil under 1500 ft. in elevation. The warty variety prefers a dry sandy or a stony soil, which is generally of a poor quality; while the pubescent variety, which attains the largest dimensions, thrives best on moist, sandy-loamy soil. Even a very considerable amount of soil-moisture is by no means prejudicial to this latter kind, provided always that this is not allowed to remain stagnant about the roots.

Cultivation.—Birch is raised from seed, which is generally ready for gathering about the end of September or very early in October. When gathered, it should be kept in a dry and airy loft, and sown in March, on beds about 3½ ft. broad. In the south of England, and especially on sandy soil with a warm exposure, the seed may sometimes be matured in August, and fall so as to germinate before the vegetative season closes. Where such is the case, the young seedlings can easily be bedded in the nursery during the following spring, for seed that has been stored over the winter takes four or five weeks to germinate, and loses in quality generally. The earth upon which Birch-seed is sown should be light and very finely worked and pulverised by spade and rake; while care should be taken only to give the slightest covering of earth of the finest quality. When the soil is coarse, it is best to give the seed no covering at all, but merely sow upon the bed and firm it down lightly with the back of the spade.

Early in June the seedlings will come up thickly, after which the beds will have to be carefully weeded. One year after sowing the seedlings may be transplanted into rows, and may be planted out after standing there two years; but if wanted of large size, they can remain another year in the nursery.

The Birch is a good tree for soon making cover on exposed parts of an enclosure where there is little soil, and that only of inferior quality. As a coppice-wood it occasionally answers well, though its characteristic demand for light does not render it suitable for underwood below standards.

Sylvicultural Characteristics.—As a woodland tree the Birch in many respects resembles the Aspen. It is certainly the most essentially *light-demanding* among the broad-leaved trees, and, like all light-demanding trees, forms rather a deep root-system. From Ebermayer's analyses it appears not only to make smaller demands for mineral nutrients than any other species of broad-leaved tree except the Common Alder (which agrees with sylvicultural experience), but also to require rather larger quantities of soil-moisture for transpiration through its foliage than Sycamore; and, in this respect, it stands on almost the same level as the Rowan or Mountain-Ash, which is very often to be found growing along with it. When, therefore, the warty variety thrives on soil that is apparently dry at the surface, it is still able to draw large supplies of water by means of its deep and wide-spreading roots. It is also endowed with the other characteristics of essentially light-demanding trees,—rapidity of growth, and a lightly foliaged crown. As it is at the same time a hardy tree, it is a good nurse to sensitive kinds like Oak, Ash, Sweet-Chestnut, Beech, or Silver Fir. But when once its period of useful service is at an end in this respect, it is often hard to get rid of the Birch; for on good soil it possesses great capacity for throwing out shoots from the stool, and sometimes also of producing root-suckers. But its power of throwing up stool-shoots is continuous, and one of the best ways of keeping Birch down is to coppice regularly for broom-making.

With its thin crown and light annual fall of foliage, the Birch is not naturally endowed with the qualities desirable in any tree forming pure woods; and though such crops are to be seen in many parts of Scotland, they are merely casual examples of the general fact that our woodlands are not managed on business principles. Where the Birch can thrive in pure woods, the soil would probably grow a better crop with profit.

Birch attains its best development when growing in mixed woods along with other species like Aspen and Alder on moist localities, or with Scots Pine on drier situations. For admixture with Spruce or Douglas Fir it is less suitable, as its long whip-like twigs damage their leading-shoots. And it further resembles the Aspen by being the host upon whose leaves the fungus *Melampsora betulina* has its change of generation for the production of *Cæoma Laricis* on the foliage of the Larch. Under favourable circumstances it can hold out a rotation of sixty to eighty years; but it will usually have to be cut out at about forty to sixty years of age, when it begins to make large demands for growing-space. When trees stand near areas about to undergo regeneration, they should be felled; for it is a prolific seed-producer, and the light seed is easily wafted to great distances, where it may perhaps spring up as a troublesome weed on areas undergoing regeneration.

(2) THE PAPER BIRCH, *Betula papyracea* Dryand.

SYNONYMS—*B. papyrifera* Mich.; *B. lanceolata* Hort.

Specific Character.—*Leaves* ovate, acuminate, doubly serrate; veins hairy beneath; petiole glabrous. *Female catkins* on long footstalks, drooping; scales having the side-lobes short, somewhat orbiculate. *Flowers* greenish-white; May and June. *Fruit* brown; ripe in October (Loudon).

Distribution.—The Paper Birch is a native of North America, and was introduced into Britain in 1750. Like the Tall Birch, it is plentiful on good land all over Upper Canada; but it prefers the drier soil, whilst the former prefers that of a moist nature.

Description.—In Canada specimens of the Paper Birch not unfrequently grow from 90 to 100 ft. in height, with a stem exceeding 4½ ft. in diameter; but in general it does not attain much over 70 ft. in height, with a stem of from 2½ to 3 ft. in diameter. It has a straight round bole, upon which the tough outer layer of bark, in fissuring, forms long rolls like paper (hence its botanical name). It is a very hardy species, little apt to suffer from frost. It possesses, like the Tall Birch, an arboricultural value only, and is of no account for woodlands. It is easily known from the Tall Birch by its leaves being smaller and of a darker green. Its branches are also more slender, and its bark is more silvery and shining. It forms a beautiful object in the Canadian forests, furnishing a good contrast with the Limes, Maples, and other trees. The Indians strip the stems and make their canoes from the bark of this tree. It is an ornamental tree in a park, its beautiful white bark contrasting well with the thick dark-green foliage. It is as easy of cultivation as the Common Birch; and being of stronger growth, produces a quicker effect. The large leaves are easily agitated by wind; and when fluttering in the breeze, they contrast well with the bright silvery stems.

Soil and Situation.—This tree requires a deep, dry, and humose soil, such as gentle knolls and ridges having a dry subsoil. Like the Tall Birch, it will not succeed on any exposed site, but should have a low-lying situation, with the shelter of other trees.

Cultivation.—The Paper Birch is grown from seed in much the same way as the Common Birch. The seeds can easily be obtained from America, if necessary.

(3) THE TALL or GOLDEN BIRCH, *Betula lutea* Mich.

SYNONYM—*B. excelsa* Dryand.

Specific Character.—*Leaves* ovate, acute, serrated; petioles pubescent, shorter than the peduncles. Scales of the strobiles having the side-lobes roundish. *Flowers* greenish-white; May. *Fruit* brownish; ripe in October (Loudon).

Distribution.—This tree is a native of North America, and was introduced into Britain in 1767. It is chiefly to be found on deep and rather moist land throughout Upper Canada, especially in the valley of the Ottawa, where it occurs very plentifully in the natural forests.

Description.—The leaves of this tree are much larger than those of the Common Birch, being generally from 3 to 4 in. long, and from 2 to 3 in. broad, and with sharp irregular teeth on their margins. In the natural forests of Canada it often grows to a height of from 80 to 90 ft., with a stem from 2½ to 3½ ft. in diameter, and sometimes even to a height of 95 ft., with a stem nearly 4 ft. in diameter. When standing alone it is highly ornamental, being clothed with branches and thickly foliaged down nearly to the ground. For Britain it possesses merely an arboricultural value, as it rarely assumes large dimensions. As a forest-tree it cannot be compared to our own indigenous Birch. With its soft pubescent young shoots and its bronze-yellow bark, however, it forms a very agreeable and striking feature near the margin of ponds or streams.

Soil and Situation.—The Tall Birch requires a good, deep, and rather moist soil and a well-sheltered situation. Although it is quite hardy enough to stand the climate of Britain, still it will not grow to a good size unless sheltered by other trees.

Cultivation.—It is chiefly grown from seed imported from America. It is as easily raised from seed as the Common Birch, and the same treatment is necessary in each case.

10. THE ALDER, *Alnus* (Linnæan System, Monœcia Tetrandria).

Generic Character.—*Barren flowers* numerous, aggregate, in a loose cylindrical catkin. *Calyx* a permanent wedge-shaped scale, 3-flowered, with two very minute lateral scales. *Corolla* composed of 3 equal florets. *Filaments* 4, from the tube of the corolla. *Anthers* of two round lobes. *Fertile flowers* fewer, aggregate, in an oval firm catkin. *Calyx* a permanent wedge-shaped scale, 2-flowered. *Corolla* none. *Styles* 2. *Stigma* simple. *Nut* ovate, without wings (Loudon).

Of the fourteen species of Alder known throughout Europe, Asia, and America, only eight are found in Central and Western Europe. These are all small trees, some of them being mere shrubs; and none are ornamental. It is only necessary to refer here to the Common Alder (*A. glutinosa*), a useful tree on cold, wet land, where few other trees can be cultivated with profit. The other two species most frequently seen, the White Alder (*A. incana*) and the Cut-leaf Alder (*A. laciniata*), possess only an arboricultural interest.

THE COMMON ALDER, *Alnus glutinosa* Medic.

Synonyms—*Betula alnus* L.; *B. emarginata* Ehrh.; *B. glutinosa* Lamk.

Specific Character.—*Leaves* roundish, wedge-shaped, wavy, serrated, glutinous, rather abrupt; downy at the branching of the veins beneath. *Flowers* brownish; March and April. *Fruit* brown; ripe in October (Loudon).

Distribution.—The Common Alder, one of our comparatively few indigenous trees, is found all over Europe, and always in moist places, such as swamps and river-banks, too wet for either Willow or Poplar. It also occurs along all the northern parts of Asia, and in the north of Africa. Its horizontal distribution coincides to a large extent with that of its near relative the Common Birch. Although it does not stretch so far northwards towards the polar limit of growth, it reaches somewhat farther south. But it lags far behind the Birch with regard to vertical distribution, for, even throughout Central and Southern Europe, it remains a tree of the plains and low-lying localities rather than of the hills.

Its finest development is attained in Western Russia and Eastern Prussia, where vast **Alder-marshes** are occupied by this species either in pure woods or in admixture with Birch and Aspen chiefly; but Oak, Ash, Elm, Maple, Sycamore, Lime, Pine, and Spruce are all often to be found associated with it there on the classes of soil best suited for their respective requirements. Under these circumstances it there grows to a height of from 50 to 60 ft.

Description.—From an arboricultural point of view, the Alder is rather a disappointing tree. Although during the summer months its thick dark-green foliage is of a pleasing colour, yet the outline of the tree is heavy and formal; and when the autumn comes it does not contribute much to the forest tints, as most of the leaves (Fig. 20) drop off without even temporarily changing their colour. In Alder-groves the trees seldom grow more than 40 ft. high; but where drawn up in close canopy along with other trees on a good loamy soil, they can attain a height of 50 to 60 ft., with a proportionate girth. But in no case will it grow to large size unless it has plenty of moisture for its roots, as on the banks of rivers. The bark of old trees is nearly black, and is full of clefts. When the tree is still young and vigorous, the branches have a triangular form; but they are round when mature. When once the Alder begins to produce seed, about the fifteenth to twentieth year, its hitherto rapid growth in height reaches its culminating point, and is only inconsiderable thereafter. Hence, when worked as coppice with a rotation of twenty to thirty years, the soil can be made to yield more timber than with any longer period of rotation.

Fig. 20.

Leaf and catkins of the Common Alder (A. glutinosa).

Economic Value.—The wood has an average sp. gr. of 0·83 when green and 0·54 after seasoning. When used in places where it is nearly always under water, or kept wet and shut off from the atmosphere, it is endowed with considerable durability; but otherwise it is soon apt to become worm-eaten and rotten. It is of no use for fencing, as posts rot near the ground in a year. Both as a tree-crop and as a coppice-wood it is used for charcoal-making for powder, and for sawing up into herring-barrel staves; while it is still largely used for clog-soles, and fetches from 4d. to 5d. per cubic foot for this purpose.

On the Continent it is chiefly used for the manufacture of cigar-boxes, for which its light, reddish, cedar-like wood is well adapted. Even in such small matters fashion and habit are all-powerful; and white cigar-boxes of Willow or Poplar, although equally good for practical purposes, would not command the same market-price as those of the hitherto prevailing colour. Coppice-woods of Alder worked with a rotation of thirty to forty years often yield very good financial returns; but good soil suitable for Alder-woods is generally capable of being drained and more profitably utilised as meadow-land.

Soil and Situation.—The Alder is by no means particular as regards quality of soil, but moisture is indispensable. Throughout the Highlands of Scotland, and in some of the hilly parts of Northern England, it grows abundantly on swampy low-lying ground, and on the margins of rivulets. The most favourable conditions for its growth are offered where the atmosphere is humid and the soil moist. It is a tree of low-lying situations, and, when ascending hillsides to any considerable elevation, is almost entirely confined to the immediate vicinity of the brooks and streams, where it can obtain abundant supplies of moisture. It does not form any decided tap-root, but develops a large number of thin strands, which gradually extend themselves deeper down into the soil, and produce large quantities of suction-roots. It can generally thrive where Willow and Poplar do well, but these will usually prove the more profitable crop.

Cultivation.—The Alder is best grown from seed, though it can also be raised from cuttings and layers, as is the method adopted in propagating such specific varieties as the Cut-leaf Alder (*A. laciniata*) and others, in order to retain their peculiar characteristics.

The ripe catkins should be gathered in October, whenever their scales begin to open. They should be spread on a sheet and exposed for a few days to sunshine, when the scales will open wide enough to allow the seed to be separated by a slight rubbing and turning with the hands. The seeds will also fall out of their own accord, if the catkins are merely stored in a dry room and turned from time to time. The seed should be sown in March, and only slightly covered. When one year old, the seedlings should be transplanted into nursery-rows, and allowed to remain there one or two years, according to the height required.

Sylvicultural Characteristics of Alder.—In many cases, soil suitable for Alder may be drained to serve a higher purpose as meadow-land. Alder plantations grow rapidly, and soon yield wood of marketable dimensions. Alder shoots well from the stool, although not, like the White Alder (*A. incana*), endowed with any considerable capacity for throwing up root-suckers. Its foliage is not insensitive to late frosts; but when young shoots have been injured, they are soon replaced by a new flush. More damage is often done to it when floods occur at the time the buds are opening in spring.

Whilst, like all other trees, thriving best when its foliage is fully exposed to light and air, it is not so essentially *light-demanding* as many others. But on inferior soil, not sufficiently moist to suit it well, it requires a large growing-space, and has altogether less vigour. On good soil, however, it forms thick coppice-woods, and, worked with a rotation of about twenty-five to thirty years, can yield good returns if there is any local market near at hand. When grown under standards of Oak and Ash, it can endure a considerable amount of shade; but under such circumstances the yield from the Alder is of course not large. Too low a period of rotation undermines the reproductivity of Alder coppice; for then the reserves of nutrients stored up in the stools gradually get exhausted, the growth of stool-shoots becomes sparse, and the soil gets overrun with rank grass.

Alder seeds freely from about the fifteenth to twentieth year; and as the seed is small, the seed-beds hardly require any covering with soil. The seedlings are slow of growth after germination, but can attain a height of about 1 ft. before autumn. They bear transplanting well, and plants of even 6 or 7 ft. in height may be easily and safely removed. Natural regeneration of an Alder highwood is not to be recommended, for the wet localities on which its cultivation is profitable have a natural tendency to rank growth of grass and herbage, which interfere with the thriving of the young seedlings. And for the same reason sowing is less reliable than planting.

The White Alder (*A. incana*) coppices well, throwing up suckers and stool-shoots freely; and it can bear a considerable degree of shade. In Germany it is found very useful in planting shallow-soiled stretches of poor limestone. Although the Alders both prefer in general a moist soil, yet the White Alder seems capable of growing fairly well even on very dry land.

PLATANEÆ Clarke.

11. THE PLANE-TREE, *Platanus* (Linnæan System, Monœcia Polyandria).

Generic Character.—*Flowers* unisexual, collected into globose or oblong catkins of different sexes, involucrated or naked. *Male flower* having the perianth composed of numerous small linear pieces, intermixed with the stamens. *Female flower* with the scales absent, or intermixed with the flowers; perianth adhering to the ovarium, cup-shaped, or ending in small pilose bristles. *Carpels* 1 or 2, 1-celled, horned at apex, coriaceous. *Seeds* solitary in the cells, pendulous. *Albumen* none (Loudon).

Of five known species of Plane, four belong to North America, but none to Western Europe. Only two species need here be referred to—the Oriental Plane (*P. orientalis*) and the American Plane (*P. occidentalis*), which are the best known and the most ornamental. These are by some botanists considered mere varieties of one species—*P. vulgaris* Spach. This may quite easily be the case, for the differentiating influence of climate may similarly be noted in the case of the Black Pines—*i.e.*, the Austrian Pine (*Pinus austriaca*) and the Corsican Pine (*Pinus Laricio*)—which are recognised abroad as one species, but are regarded as two independent species by British arboriculturists. For Britain the Planes possess merely an arboricultural interest. Both ripen seeds in Britain during warm seasons, and both possess strong power of shooting from the stool. This would render them well adapted for coppicing and pollarding, if the wound-surfaces were less apt to become spotted and rotted by fungous disease.

(1) **ORIENTAL PLANE-TREE,** *Platanus orientalis* L.

Specific Character.—*Leaves* 5-lobed, palmate, wedge-shaped at the base; the divisions lanceolate, sinuated. Stipules nearly entire. *Flowers* greenish-yellow; April, May. *Fruit* brown; ripe in October; persistent great part of the winter (Loudon).

Distribution.—The Oriental Plane-tree is indigenous to the Levant, Asia Minor, and eastwards as far as Persia, Turkestan, and Afghanistan. It was introduced into Britain in the sixteenth century. It is found on Mount Etna at an elevation of 2000 ft. above the sea-level; but in the Steppes it ascends the Taurus range to a height of 5000 ft. It is also of true forest-growth in Greece and on the outlying ranges of Mount Athos. It seldom attains its full dimensions as a timber-tree except in low-lying and level parts of the country, on a light deep soil, in the neighbourhood of running water.

Description.—The Oriental Plane grows to a height of 60 to 80 ft., with a stem of 3 to 6 ft. in diameter. It is a very handsome and massive tree, which grows quickly, and, along with the Western Plane, is one of the chief trees planted along avenues, boulevards, parks, &c., in towns and cities. These two species are thus usually distinguishable :—

Species.	Bark in winter.	Leaves.	Flowers.	Fruits.
P. orientalis.	Scales very freely.	Deeply cleft, palmate; wedge- or heart-shaped at base, and generally with 5 main nerves and lobes (seldom 3); with short and mostly green petioles.	Greenish-yellow; April, May.	Seed-ball catkins rough, and generally 2 or 3 on each spike; more or less persistent throughout winter.
P. occidentalis.	Scales much less freely, and hardly at all from young trees.	Slightly lobed, and more like those of Norway Maple; not usually heart-shaped, but rounded off at base, and generally with only 3 main nerves and lobes (seldom 5); downy beneath; with red petioles.	Greenish; May	Seed-ball catkins smooth, and generally solitary on the spike.

Further distinctions are that in the Western Plane the young foliage and leaf-stalks are usually covered with a yellowish-white primrose bloom, and the stalks are of a reddish-brown colour; while in the Oriental Plane the young leaves are pubescent on the under surface only, and the leaf-stalks are shorter and mostly green.

These characteristic differences in foliage have apparently now become almost entirely lost by hybridisation. During the spring of 1904 I saw many thousands of Plane-trees in Southern and Central France, and never observed any which had not the *bark* of the Oriental species and the *leaf* of the Western.

All over Europe this and the Western Plane are now *par excellence* the trees of the parks, public gardens, avenues, roadways, &c., owing to their power of resisting the noxious influence of atmospheric impurities, as well as to their ornamental appearance. A variety of the Oriental Plane, sometimes known as *P. acerifolia* on account of a resemblance to the leaf of the Norway Maple,[1] is common in the London parks, and can thrive better than most other trees in the smoke-laden atmosphere. Variations of the Oriental Plane are very frequent: both hardy and tender varieties are often produced simultaneously from seed collected not only from one tree, but even from one catkin.

Economic Value.—The wood of the Plane-tree is usually yellowish-white and hard, though in warmer climates it is of a reddish colour. It has large pores and is a light wood, having a sp. gr. of only 0·58 when seasoned. Its annual layers are intersected by numerous medullary rays. Its timber is of good quality, and large stems furnish ornamental planks much used for in-

[1] It is, however, easily distinguished from the Maples (although the leaves of the Maple are somewhat similarly shaped, and the bark of the Sycamore also scales off in flakes to a slight degree),—in the winter season, by the alternating arrangement of its buds; and in the summer season, by its leaves having *five* main nerves or veins (not *seven* as in the Maple), and having stipules, and also by not being arranged in opposite pairs like Maple leaves (see also p. 141).

terior decorative work in Southern Europe. Like the Lime, its wood is also used as a frame-work for veneering in furniture-making. The chief value of this tree in Britain will always be for planting in towns and smoky cities.

Soil and Situation.—Both this and the American Plane grow best on a deep, light, moist, and humose soil, and in a sheltered position; and they can stand a good deal of soil-moisture, though rather sensitive (especially *P. orientalis*) to late frosts in damp hollows. They do not thrive on stiff clay or in exposed positions. On the whole, they may be said to be fairly accommodating; but soil that is either very dry or very wet, or that contains a large percentage of lime, is not favourable. In respect of lime, however, it is not so sensitive as the Sweet-Chestnut and the Maritime Pine, upon whose growth carbonate of lime acts very prejudicially.

Fig. 21.

Oriental Plane-tree leaf (about ⅓ natural size).

Cultivation.—The Plane-tree may be grown from seed; but layers, which root freely, and cuttings, which strike as easily as Willow or Poplar, are the cheapest and simplest method of cultivation. The best way of reproduction is to make slips from the one- and two-year-old wood, and set them (like Willows) about a foot apart in good, light, nursery soil; and when two or three buds are left above ground they soon shoot from these, and can be transplanted into the nursery-rows during the spring.

If it be desired to raise it from seed, the fruits, which ripen plentifully in Britain during dry warm seasons, should be gathered in October or November, the balls being broken by hand or by threshing with a light flail, when the seeds may easily be husked and cleaned. The seed may either be sown in the nursery immediately (as is the usual custom), or else mixed with sand and kept in a dry place, secure from frost, till February or March. It should be sown on moist rich soil in a shady situation, and should only, like the seed of Birch, Elm, or Alder, be covered very lightly, or merely made to adhere to the soil by being firmed down with the back of the spade, and not covered at all. But in this latter case the seed-beds need to be protected with litter of some sort, to prevent damage from the winter frosts. The plants come up during the following spring.

(2) AMERICAN or WESTERN PLANE-TREE, *Platanus occidentalis* L.

Specific Character.—*Leaves* 5-angled, obsoletely lobed, dentate, wedge-shaped at the base; downy beneath. *Flowers* greenish; May. *Fruit* brownish; ripe in October and November (Loudon).

Distribution.—The American Plane is found over a large extent of the North American continent, from the eastern seaboard to the Western States, and from the southern parts of Canada southwards to the Carolinas. It is plentiful on the sides of rivers in the State of Pennsylvania, and also on the Grand River in Canada; but is hardly ever found on dry inland parts far removed from the rivers.

In Europe it is more extensively cultivated throughout Southern Germany and Austria than elsewhere, and is there frequently planted in avenues. It is, however, capable of being cultivated everywhere throughout Britain, as it grows and flowers as far north as 58° in Western Norway. It is of rapid growth, and yields a fairly good wood for many ordinary purposes.

Description.—This species has much in common with the Oriental Plane, but is on the whole of stiffer outline and rather less ornamental, though of more rapid growth and of a more upright habit, especially when planted on low-lying land near a stream.

Economic Value, Soil and Situation.—As for the Oriental Plane.

Cultivation.—If it be desired to grow it from seed, the seeds should be sown in a cold frame in February or March, and shaded from the sun. Afterwards they should be gradually exposed till they are accustomed to the sunshine; and when they have become hardy enough the frame should be removed, and the plants left to themselves to mature their growth in the open air. During the following season they will be fit for transplanting to the nursery-lines.

Like the Oriental Plane, this species may best be reproduced from layers or slips, which root quite freely and form excellent plants.

CARPINEÆ Döll.

The *Carpineæ* (or *Corylaceæ* of A. de Candolle) is a family scattered throughout the temperate zone of the northern hemisphere, and especially frequent in Central Asia and eastwards to Japan. It consists of 4 genera and 18 species, of which 3 genera and 6 species occur in Central and Southern Europe. These three genera are thus distinguishable (Wilkomm):—

I. *Coryleæ.* Nut ⅝ to 1½ in. in length, and either covered or hidden by the envelope formed by the bracts. **Hazel** . . . . *Corylus.*

II. *Carpineæ.* Nut ¼ to ⅓ of an in. in length.

1. Nut encircled at the base by a large flat-lobed or indented toothed bract. **Hornbeam** . . . . *Carpinus.*
2. Nut enclosed in a hollow, conical, net-veined bract. **Hop-beech** . *Ostrya.*

Of these, only the Hazel (*Corylus*) is indigenous to Britain, whilst the Hornbeam (*Carpinus*) was introduced in the fifteenth century. The Hop-Beech (*Ostrya*) is of more recent introduction, and is almost solely confined to arboreta and botanic gardens; even in its own home throughout Southern Europe it plays a comparatively unimportant part as a woodland tree.

12. THE HAZEL, *Corylus* (Linnæan System, Monœcia Polyandria).

Generic Character.—*Flowers* monœcious. *Male flowers* in compact cylindrical catkins with imbricated catkin-scales. *Female flowers* solitary or in pairs in terminal scaly buds, each flower or pair of flowers surrounded by a bell-shaped involucre: *ovary* 2-celled, with 1 ovule in each: *styles* 2, stigmatiferous throughout, erect. *Nut* ovoid or oblong-ovoid, solitary, 1-celled and 1- (rarely 2-) seeded, wholly or partially enclosed in a coriaceous or subfoliaceous cupule, with a laciniate margin.

Shrubs with herbaceous-scaled buds and deciduous serrate leaves (Sowerby).

THE HAZEL, *Corylus avellana* L.

Specific Character.—*Leaves* on a short leaf-stalk, obovate, roundish, pointed, and with a doubly serrate edge. *Male catkins* formed in summer, and remaining closed throughout winter, mostly in 2-4 on leafless shoots at the end of the previous year's twigs. *Female catkins* enclosed in buds, which produce a bunch of carmine-red pistils when flowering, some weeks before the leaves are flushed. *Nuts* ripen and fall in autumn.

Distribution.—The Hazel is found throughout all Europe except the extreme north, and it is also a native of Algiers and Asia Minor.

Description.—Even when allowed to grow to its full height, Hazel is nothing more than a shrub of 20 to 22 ft. high. In our woodlands it is only to be found in the coppices. There it is one of the dominant and most distinctive kinds of underwood throughout the old Oak-woods and copses, where it is either grown pure or along with Ash, Chestnut, Willow, Birch, &c.; and along with Ash and Chestnut, it forms the most profitable part of the coppice-crops.

Economic Value.—Hazel possesses special value as coppice-wood, because the long straight shoots can usually be easily disposed of as hoops for barrels, withes for hurdle-making, &c. It has good reproductive capacity, sending out numerous straight shoots from the stool whenever it is cut back, which often take root for themselves. It can be worked with any rotation (up to fourteen or sixteen years) that will best suit Ash, Chestnut, or Oak forming the rest of the coppice. Hazel can bear a good deal of shade under standards of Oak, Ash, &c.; but of course the profit obtainable from the underwood diminishes according to the amount of overhead shade which the underwood has to contend against. Unfortunately it is (like the Ash) much liable to be attacked by rabbits, which often in England clear the Hazel underwood as if it had been cut away.

Soil and Situation.—Hazel thrives on all kinds of soil, but grows and reproduces itself best on fresh or moist limy, loamy, alluvial, or humose land. Inferior sandy soil or sour marshy land and heavy clay are not well suited for it. Even on shallow rocky hillsides it can often yield a fair return, when a mere handful of earth here and there enables it to establish itself, and in such situations its heavy fall of leaves annually tends to form more soil.

Cultivation.—Hazel layers or "plashes" well, and can therefore be used for filling up blank spaces in the underwoods by bending back old stool-shoots left on purpose and layering them under sods of turf. As most of the coppices and copse-woods in England are much too sparse and thinly stocked, this method deserves a trial wherever it can conveniently be adopted, as it has the merits of being cheap and effective. When plants are needed for filling up blanks in existing plantations, or for underplanting, or forming new coppice-woods, layering will produce good plants more quickly than growing them from seed. Plants can be easily raised from the nuts, however, though seedlings are nothing like so quick-growing as rooted layers.

13. THE HORNBEAM, *Carpinus* (Linnæan System, Monœcia Polyandria).

Generic Character. — *Male flowers: Catkins* lateral, sessile, cylindrical. *Bracteas* imbricate. *Flowers* consisting of 12 or more stamens inserted at the base of a bractea. *Anthers* bearded at the tip, 1-celled. *Female flowers* in lax terminal catkins. *Bracteas* of two kinds, outer and inner: outer bracteas entire, soon falling off; inner bracteas in pairs, each 3-lobed. *Calyx* clothing the ovary to near its tip, and adhering to it; toothed at the tip. *Style* very short. *Stigmas* 2, long, thread-shaped. *Fruit* not attended by the involucre; ovate, compressed, ribbed, clothed, except at the base, and tipped with the adnate calyx; woody; including one seed (Loudon).

Only one species of this genus need be referred to here—viz., the Common Hornbeam (*C. Betulus*), as it is the chief timber-tree of the family, is very hardy, and under favourable circumstances attains considerable proportions.

THE COMMON HORNBEAM, *Carpinus Betulus* L.

Specific Character.—*Bracteas* of the fruit flat, oblong, serrated, with two lateral lobes. *Flowers* yellowish; May. *Nuts* brown; ripe in October or November (Loudon).

Distribution.—The Hornbeam is a native of all parts of Central Europe, and is also found in Italy, the south of Russia, and the west of Asia. It is indigenous to England, Ireland, and the southern parts of Scotland.

Description.—On a good loamy soil Hornbeam grows to 60 or 70 ft. high, and has a stem of 2 to 3 ft. in diameter. This, however, is very exceptional, and more often there is a strong tendency to ramification and a short stem. Its spreading crown of thick foliage is distinctly ornamental, but it is a tree that receives little attention in Britain, though it might often in landscape gardening find a suitable place in damp spots, where its hardiness against frost gives it a special recommendation. As a matter of fact, it is chiefly to be found in our hedgerows, for which its strong reproductive power and its capacity for standing pruning and cutting back make it eminently suitable. The Hornbeam is very easily distinguishable from the Beech by the usual fluted growth of its stem. The leaves are ranged on the twig in the same manner and correspond as regards size and outline; but the Hornbeam-leaf is doubly serrate, while the Beech-leaf has an entire edge. There is also a great difference in the seed or nuts, which have a flat, leafy, three-lobed appendage (Fig. 22). During winter the buds are smaller than those of the Beech, and the slightly bent side-buds are always pressed closely down against the twigs. During the development of the buds annually large numbers of diminutive adventitious buds are also formed near the base of the bud-axis, and when the twigs are clipped or removed these attain development. It is to this fact that its special adaptability for hedging purposes is attributable.

Fig. 22.

Winged fruit of the Hornbeam (Carpinus Betulus).

Except in Western Russia, where it reaches its finest dimensions and takes the place of the Beech as a forest-tree, it does not usually grow to more than 60 ft. in height, with a stem of about 2 to $2\frac{1}{2}$ ft. in diameter. Nor does it attain so high an age as the Beech, for after about its 100th to 120th year it is apt to become *stag-headed* and unsound in the bole. But it retains its reproductive capacity of shooting from the stool to about 90 years, like the Oak. In many parts of England the Hornbeam grows to 70 ft. in height, with a stem of from $2\frac{1}{2}$ to 3 ft. in diameter. In Scotland it attains a height of from 50 to 60 ft., with stems over $2\frac{1}{2}$ ft. in diameter. It usually begins to exhibit signs of decay about the 100th to 120th year, and seldom reaches over 150 years of age.

Economic Value.—The wood of the Hornbeam is white, and very hard, tough, and heavy. It has a sp. gr. of 1·05 when green and 0·74 when seasoned, so that it is at least as heavy as the Sessile Oak. It is very cross-grained and difficult to work, but otherwise is used for much the same purposes as Beech. It is only durable when used in dry places. It makes excellent fuel and charcoal of the best quality. In Britain it is seldom large enough to be of much value as timber. On the Continent, owing to its extreme toughness, it is prized as cogs for machinery, and is largely used for making carts, moulds, boxes for planes, wedges, working-benches, flails, agricultural implements, wooden pegs for shoes, &c. It is difficult to split, and shrinks a good deal. Of all the European woods it possesses the greatest heat-producing power as fuel, the list being headed by Hornbeam, Beech, and Birch.

Soil and Situation.—The Hornbeam thrives best on a fresh or moist, deep, loamy-sandy or rich marshy land, and on fresh loamy or limy and deep sandy soil. On shallow, dry soil with warm sunny exposure, as also on soil that is constantly more or less wet, it does not grow to any large size. As a hedge-plant it grows well on most soils, unless they are chalky (when Beech is far preferable).

Cultivation.—The nut ripens in England, but not generally in Scotland. It should be gathered and sown in October, as it generally lies dormant for one year in the ground before germinating; or the seed may be stored for a year and then sown out, when it germinates in the following spring. The seedlings should be put into the nursery-lines when one year old, and allowed to stand for two years before removal.

The Hornbeam can hardly be said to be of any **Sylvicultural Importance** in Britain. Its chief claim to attention rests on its shade-enduring capacity, in which it resembles, but does not quite equal, the Beech, and in its undoubtedly strong power of reproducing itself by shoots from the stool. It may therefore occasionally be of value for underplanting Oak where the soil is somewhat too moist for Beech. Throughout Britain, however, thanks to our damp climate, the same object can very often be attained quite efficiently by underwood of other trees offering fairer prospects of profit. In coppice-woods, when felling takes place deep down near the ground, Hornbeam often throws out suckers as well as stool-shoots.

As it bears seed freely from about the age of thirty years, and as the long bract attached to it enables the seed to be borne far by the wind in autumn, all Hornbeam-trees should be cleared away from places near which crops of Oak or Beech are being regenerated naturally. For the Hornbeam springs up easily, and is often difficult to exterminate owing to its great reproductive power. It is one of the hardiest species of trees against late frosts, and is therefore specially adapted for undergrowth in damp low-lying tracts, where less hardy species fail to thrive. Underwood may easily be formed either by sowing or planting.

HIPPOCASTANEÆ DC.

14. THE HORSE-CHESTNUT, *Æsculus*
(Linnæan System, Heptandria Monogynia).

Generic Character.—*Calyx* campanulate. *Petals* 4-5, expanded, with an ovate border. *Stamens* with the filaments recurved inwardly. *Capsules* echinated. *Leaflets* sessile, or almost sessile. *Leaves* palmately divided, with stalked leaflets, generally rough. *Capsule* rough (Loudon).

This is a widespread genus throughout Europe, Asia, and America, but the only species that need here be referred to is the Horse-Chestnut (*Æsculus Hippocastanum*), so called from the fact that the Greeks and Turks used the seed medicinally for the cure of glanders and pulmonary diseases in horses.

Through the whole of Central and Western Europe the Horse-Chestnuts are favourite trees for avenues and ornamental planting in towns, not only on account of the beauty of their flowers in early spring, but also of the fulness of their foliage throughout the summer. There are several kinds of Horse-Chestnuts, but in England the Common Horse-Chestnut is the only species that is to be met with frequently. These others include the Red Horse-Chestnut (*A. carnea* Willd.) and the two American species (the genus *Pavia* of Boerh.), the Yellow Buckeye (*Æsculus flava* Ait. = *Pavia flava* Mnch.) and the rarer Purple Buckeye (*Æsculus pavia* L. = *P. rubra* Lamk.) The first-mentioned is probably a hybrid of the Common and the Purple Horse-Chestnut.

THE COMMON HORSE-CHESTNUT, *Æsculus Hippocastanum* L.

SYNONYM—*Hippocastanum vulgare* Gaertn.

Specific Character.—*Leaflets* 7, obovately cuneated, acute, and toothed. *Flowers* white, tinged with red; May. *Fruit* brown; ripe in October. *Buds* long, large, greenish-brown, covered with resin (Loudon).

Distribution.—This tree is indigenous to the mountains of Greece at elevations of 3300 to 4500 ft., where it grows along with Walnut, Plane, Ash, Oaks, and Holly. It also occurs in many parts of Asia, whence it was introduced into Britain about 1629. A closely related species grows extensively in the Himalayas (*Æ. indica* Colebr. = *Pavia indica* Royle), and another in Upper Burma and Assam (*Æ. assamica*).

Description.—The Horse-Chestnut grows rapidly and to a large size, being often 70 to 80 ft. high and 4 to 6 ft. in diameter. It is a hardy tree as regards climate, but its branches are easily broken by wind in exposed situations. Though its crown is formal in outline, its widespreading branches have a picturesque effect; and as the foliage and the rich pinkish-white flowers flush early in spring, it forms a very fine avenue tree.[1] In winter it is not seen at its best, the branches being few and formal, with curving, upturned ends suggestive of a candelabrum. The rapid growth of the young wood of this tree is remarkable, the shoots of the year being generally hardened within one month from the time the leaves flush. The crown is very liable to be killed by an infectious fungous disease (*Nectria cinnabarina*), the bright-red pustules of which may often be noticed before the branches die and rot off. When planted in towns, its lower branches need pruning to check their spreading too far; but it does not thrive well in a very smoky atmosphere.

Economic Value.—The wood is soft, and neither durable nor strong, though it is useful for flooring, waggon-bottoming, turnery, packing-cases, &c. On the Continent there is a fair demand for its timber by turners and cabinetmakers, and it is of special value for the purposes of carvers; otherwise its durability is not sufficient to recommend it for general use. It has a sp. gr. of 0·90 when green and 0·57 when seasoned. Like other softwoods, its timber is well adapted for the manufacture of wood-pulp and cellulose.

Soil and Situation.—To attain large dimensions and its full ornamental effect, it requires to be grown upon a good, rich, and dry loamy soil, and in rather a sheltered situation. Where late frosts are frequent, the trees are apt not to set their fruits.

Cultivation.—It is raised from the nuts, which ripen in October, and should be gathered and sown immediately, as they lose their germinative power if kept long. The seed is usually put into the prepared seed-bed in autumn, being sown in drills with about 4 inches between every two seeds. Care should be taken to have the smooth side upwards and the grey scar downwards, otherwise malformation of the root-system and weakly seedlings may result. The seedlings make vigorous shoots during their first year, and are fit for transplanting into nursery-rows when one year old. They may remain for one or for two years in the nursery, according as small or large plants may be wished.

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[1] One of the best known of such avenues is that at Bushy Park, near Hampton Court, and during the flowering-time this forms one of the sights of the season in London.

TILIACEÆ Juss.

15. THE LIME-TREE, *Tilia* (Linnæan System, Polyandria Monogynia).

Generic Character.[1]—*Calyx* 5-parted. *Petals* 5. *Stamens* numerous, free, or somewhat polyadelphous. *Ovary* globose, villous, 1-styled, 5-celled; cells 2-ovuled. *Nut* coriaceous, 1-celled, 1-2-seeded, from abortion (Loudon).

Although botanical differences exist with regard to the different kinds of Lime-trees, yet the whole genus *Tilia* is really of so little sylvicultural importance throughout Britain that it is best to class them all together (as was originally done by Linnæus),[2] and consider them as merely varieties of the common European Lime or Linden (*Tilia europæa*). There is really no difference worth mentioning in respect to the general habits and peculiarities of the trees; all require similar treatment in their general cultivation, &c. Hence reference will here be made only to the species common in Britain, which are very much superior to the others both as timber and as ornamental trees. It may be remarked, however, that the numerous varieties of the Lime-tree can easily be propagated by layering.

THE COMMON LINDEN or LIME-TREE, *Tilia europæa* L.

Synonyms—*T. parvifolia* and *T. grandifolia* Ehrh.; *T. ulmifolia* and *T. platyphyllos* Scop.; besides other synonyms for each of these two species.

Specific Character.—Petals without scales. *Leaves* cordate, acuminated, serrated, smooth, except a tuft of hair at the veins beneath, twice the length of the petioles. *Flowers* yellowish-white in many-flowered cymes; August and September. *Fruit* coriaceous, downy, yellow; ripe in October (Loudon).

Distribution.—The Lime-tree is indigenous to Central and Southern Europe and Western Asia, and was originally introduced into Britain by the Romans. The large-

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[1] Loudon, in his *Encyclopædia*, distinguished and described 4 species of the Lime-tree as natives of Britain, 3 as natives of North America, and 1 as a native of Hungary. The four described by Loudon as native species were the Common Lime-tree, *Tilia rubra;* the intermediate Lime, *T. intermedia;* the small-leaved Lime, *T. parvifolia;* and the broad-leaved Lime, *T. platyphylla.* Their specific characters were given as follows:—

1. Leaves cordate, unequal at base; petioles and suckers hairy; axil of veins beard beneath; fruit globose, smooth . . . . *T. rubra.*
2. Leaves cordate, acuminated, serrated, smooth, twice as long as stalks; axil of veins beard beneath; fruit membranous, oblong, deformed, 2-seeded *T. intermedia.*
3. Leaves cordate, round, acuminated, finely serrated, smooth, scarcely longer than stalks; axil of veins beard beneath; fruit round, very thin and brittle *T. parvifolia.*
4. Leaves cordate, round, acuminated, finely serrated, a little downy beneath; fruit turb., woody, with prominent ribs . . . . . *T. platyphylla.*

[2] The majority of Linden or Limes are indigenous to the warmer temperate zones of North America and Asia, and the few species native to Europe were by Linnæus classed as *T. europæa.* Strictly speaking, however, **there are two distinct species indigenous to Central Europe**, which are thus distinguishable:—

1. Leaves smooth; upper side dark-green; under side dull bluish-green, with rusty-brown hairs in the angles of the ribs; cymes bearing many flowers (*T. ulmifolia*, Scop.) . . . . *T. parvifolia*, Ehrh.
2. Leaves hairy; under side grass-green, shining, and with whitish hairs in the angles of the rib; cymes bearing three flowers (*T. platyphyllos*, Scop.) *T. grandifolia*, Ehrh.

leaved species, whose seeds only ripen during warm seasons, apparently died out, and was re-introduced during the eighteenth century. The short-leaved species has been cultivated in Britain from time immemorial, and is as hardy as a native tree. The Limes are essentially trees of the plain, and do not ascend the hillsides to any great elevation. Throughout Central Europe the small-leaved species occurs much more extensively than the broad-leaved kind, which is that most frequently to be found over Southern and South-eastern Europe and in South-western Asia. The former forms extensive woods throughout Western Russia, Poland, and Eastern Prussia, where it is often associated with the Oak and the Elm.

Description.—The Lime-tree is very ornamental during the month of July, when it is in full flower and when its foliage is at its finest. Though somewhat stiff and formal in outline, and not presenting the light and shade required for picturesque scenery, it is decidedly ornamental in well-chosen situations, such as along the sides of walks or avenues. Under favourable circumstances it often reaches a height of 100 ft., with a stem over 4 ft. in diameter. It lives to a great age, and often continues sound for upwards of 200 years.

The cymes of the large-leaved Linden have only three flowers, while those of the small-leaved species (Fig. 23) have more than three flowers. They both do

Fig. 23.

Leaf and fruit of the Small-leaved Lime (T. europæa *L.* = T. parvifolia *Ehrh.*).

fairly well in the impure atmosphere of towns, and are well adapted for lopping and pollarding, as they easily develop large numbers of adventitious buds near their crowns.

Economic Value.—The wood of the Lime is close, white, and soft, and is the lightest wood produced by any of the broad-leaved European trees. It has a mean sp. gr. of only 0·74 when green and 0·45 when seasoned, so that it is no heavier than Spruce. It is not durable, and even in dry places is soon attacked by insects. It is used for turnery, sounding-boards for pianos, and charcoal-making. On the Continent it is used extensively for the fabrication of wood-pulp, for packing-cases, for piano and organ manufacture, for coarse carving, and as the framework of veneers for furniture.

Soil and Situation.—The Lime-tree thrives on a great variety of soil, if not too poor and dry, and if not exposed to heavy storms. Very fine trees may sometimes be seen growing upon a strong, deep, clayey loam, with rather a moist subsoil; but as a rule it may be said to do best on a good strong loam, and in a low-lying and sheltered situation. Both the large-leaved and the small-leaved Linden require a good deep soil, upon which they make much the same demands as the Beech. But the large-leaved species makes higher demands both with respect to soil and to temperature ; and as it is at the same time the more handsome tree of the two, it should in general receive the preference for planting in parks and avenues in Southern England. For Scotland, for poorer land, and for the smoky atmosphere of towns, the small-leaved Lime is preferable. As even fairly large trees bear transplanting, the Lime-tree is useful in filling up gaps, or in forming groups to produce an immediate effect upon a lawn.

Cultivation.—The Linden is generally propagated by layers, which strike readily. Plants raised from seed are, however, better than layer-grown saplings, if intended to be planted as timber, because they are less liable than the latter to run to small branches and twigs.

The seeds should be sown as soon as received from abroad (if home-grown seed is not obtainable), because, if stored till the following spring, they will not come up equally—many of them not till the second year. Some, however, mix the seeds with sand, or very fine earth, which should neither be so dry as to extract the natural moisture from the seeds, nor so damp as to induce rot in them. If kept in sand or fine and not too dry earth, they should be sown in the following spring, and will come up equally in summer. When one year old they may be transplanted into the nursery-rows, where they can remain for one, two, or even three years, according to the size of the plants wanted. The Continental method is to sow the seed on the seed-beds as soon as gathered in autumn, the drills on the beds being about 8 in. apart, and the seed being covered with about ½ to ¾ of an inch of earth. The beds are protected in spring against early germination and danger from frost. After they are transplanted as yearlings into the nursery-beds, they are trimmed from time to time, as they often exhibit a tendency to excessive lateral development.

One can hardly speak of any **sylvicultural characteristics of the Lime** in Britain, for it is really only an ornamental tree in avenues, parks, and open spaces, and along broad roadways in towns. This latter position, once largely occupied by the Lime and the Elm, has, however, in our huge modern cities been found to be better filled by trees like the Planes, that are hardier against the injurious action of sulphurous and nitrous acids, contained in excessive quantities in the atmosphere. Wherever bee-keeping is largely in vogue, Lime-trees have a special value, as the honey-bees visit them frequently during the time of flowering in July and August.

The large-leaved Lime is of more rapid growth than the small-leaved kind, and at the age of seven or eight years transplants of the former are usually as large as ten- or eleven-year-old plants of the latter. They are provided with strong reproductive power, and are therefore not much liable to permanent damage from late frosts, as they throw out fresh shoots or foliage when twigs have been nipped. This reproductivity, combined with a fair power of bearing shade, would suit them for coppice and underwood were there any profitable market for the wood.

JUGLANDEÆ DC.

16. THE WALNUT-TREE, *Juglans* (LINNÆAN SYSTEM, MONŒCIA POLYANDRIA).

Generic Character.—*Flowers* unisexual, monœcious. *Male flowers* in cylindrical, drooping, solitary catkins. *Calyx* of 5-6 scales. *Stamens* 18 to 36. *Female flowers* solitary, or a few in a group, terminal upon a shoot developed in the same year. *Calyx* ovate, including and adhering to the ovary. *Petals* 4. *Stigmas* 2-3, fleshy. *Fruit* a drupe. *Covering* of the nut a fleshy husk of 1 piece that bursts irregularly. *Nut* woody, of 2 valves. *Leaves* compound, alternate, exstipulate, deciduous ; imparipinnate, of 5-19 leaflets, all but the terminal one in opposite or nearly opposite pairs ; all serrate, and all spreading in one plane (Loudon).

There are many species and several varieties of the Walnut, chiefly natives of North America, but the only one that need be referred to here is the Common Walnut (*Juglans regia*), which has been in cultivation in Britain since 1562 at least.

THE COMMON WALNUT-TREE, *Juglans regia* L.

Specific Character.—*Leaflets* in a leaf, 5-9; oval, glabrous, obscurely serrated. *Flowers* greenish; April and May. *Fruit* oval, situated upon a short inflexible peduncle, with a green husk enclosing a brown nut; ripe in September (Loudon).

Distribution.—The Walnut is, like the Horse-Chestnut, indigenous to the mountainous tracts of Greece, where it may frequently be found of true forest growth, along with Oaks and Chestnuts, in damp valleys and bordering the watercourses at elevations varying from about 2000 to 4000 ft. In Bosnia it also forms large pure forests, and from there it extends eastwards across the Caucasus into Persia, Northern India, and China. It is cultivated in every part of Europe, as far north as Warsaw, both for fruit and timber. In most parts of Britain lying to the south of the river Forth its fruit generally ripens, but to the north of this the fruit only matures in fine seasons.

Description.—In Britain Walnut has a thick stem and an ample crown of foliage. It grows to about 60 ft. high, and 2½ to 3 ft. in diameter. When the tree begins to get old its stem has a thick and deeply-furrowed bark, but on the branches the bark generally remains lightish-grey and smooth. The leaves, especially when bruised, have a strong aroma, often very perceptible in the warm weather of summer.

Economic Value.—Though the Walnut is generally cultivated for its fruit, there is no doubt it might be grown for its timber also. When the tree is young the timber is soft, white, and comparatively worthless, while the sapwood is thick, soft, and apt to become worm-eaten. But after it has attained 50 to 60 years of age the heartwood gradually becomes hard and solid, until at about 80 to 100 years of age it assumes a close texture and a dark-brown colour, with beautiful markings. The best quality of timber is obtainable from healthy trees above 100 years of age. Though not equal in quality to the timber produced in the hot, dry climates, where it is indigenous, that grown in England is still much sought after for furniture, and brings a high price when really good and solid. It is largely used for gun-stocks, as no other description of European wood has been found so suitable for this purpose. Throughout Southern Europe, where the Walnut attains an age of 300 to 400 years, and a diameter of about 40 in., the wood is much used for furniture. In most parts of Central Europe it ranks almost equally with mahogany for this purpose, and often fetches an equal price. But, in general throughout Northern Europe, its importance is to a far greater extent arboricultural than sylvicultural.

Soil and Situation.—To grow Walnut well and to a really valuable size, it requires to be planted in a deep and dry, but rather light loamy soil, for it throws out large, strong tap-roots, and if these get down into wet or poor subsoil the tree will not thrive. It may do well on a considerable variety of soils, if these are of a deep, light, porous, and dry nature; but it will not succeed on heavy or cold-bottomed land. Continental experience shows that even on light, deep, humose soil, the Walnut is an essentially *light-demanding* species of tree, which, in addition to free exposure to light and warmth, requires to occupy a fairly sheltered situation. It is apt to suffer damage from late frosts in May, just at the time when it breaks into foliage.

Cultivation.—This species is always grown from the nuts, which generally ripen about the beginning of October. They should be sown in rows, and covered to the depth of about 2 in. As they are very apt to lose their vitality if long kept, they should be sown as soon as possible after collection (or importation). The seedlings throw out strong tap-roots during the first year, and should be transplanted into nursery-lines when one year old. This makes them more fibrous in the root, and easier to plant out permanently. The several varieties of this tree can be propagated by budding, grafting, and layering.

For sylvicultural purposes two North American species — the Black Walnut (*J. nigra* L.) and the Grey Walnut (*J. cinerea* L.)—are said to have yielded favourable results in Continental experiments. They are of rapid growth, appear to stand the climate of Europe well, and are not particularly liable to be damaged by late frosts. In America they are trees of true forest growth, as their fruits have little edible value. The Black Walnut is ornamental, and yields splendid timber, while it is also said to be much hardier than the common species. But here it only thrives in the warmest and driest parts of England, where it produces timber of fine colour and good dimensions. In Germany it has been found suitable for growing along with Oak, as it requires much the same kind of soil.

MAGNOLIACEÆ.

17. THE TULIP-TREE, *Liriodendron*
(Linnæan System, Polyandria Polygynia).

Generic Character.—*Carpels* 1-2-seeded, disposed in spikes, indehiscent, deciduous, drawn out into a wing at the apex. *Calyx* of 3 deciduous sepals. *Corolla* of 6 petals, conniving into a bell-shaped flower (Loudon).

There is only one distinct species of this genus, the *L. tulipifera*, which is a free-growing tree, attaining a large size in this country, and especially in the southern and midland counties of England.

THE COMMON TULIP-TREE, *Liriodendron tulipifera* L.

Synonyms—*L. procera* Salisb.; *Tulipifera Liriodendron* Mill.

Specific Character.—*Leaves* smooth, truncate at the top; 4-lobed, resembling a saddle in shape. *Flowers* large, solitary, terminal, greenish-yellow without, orange within; furnished with two deciduous bracteas under flowers; June and July. *Strobile* brown; ripe in October (Loudon).

Distribution.—The Tulip-tree is indigenous to Canada and the United States as far south as Carolina and Georgia. In Upper Canada it is commoner in the south than in the north. It is also common in Tennessee and Kentucky, as well as in New York and Pennsylvania, where it is called the "Tulip Poplar." It was introduced into Europe either in 1663 or in 1688.

Description.—This tree is easily known by its characteristic truncated leaves, which have a saddle-shaped outline. In Britain the trees grow to a height of 60 to 80 ft., and 2 to 4 ft. in diameter. It grows tall and straight, with a spreading crown, covered in warm seasons with pretty cream and orange tulip-shaped flowers. It is one of the most ornamental of the broad-leaved trees introduced from North America, and is quite hardy in most parts of Britain and Ireland.

Economic Value.—Under the names of "White Wood," "Canary Wood," and "Yellow Poplar," the timber of the Tulip-tree is now used in fairly large quantities for furniture and ornamental purposes.

Soil and Situation.—Although this tree is hardy enough as regards winter cold, it is liable to suffer from late and early frosts, so that it can only be expected to thrive in sheltered situations, where it does best on a deep, well-drained, loamy soil. And as it requires a considerable amount of summer warmth, it only attains really fine growth in the warmer parts of England, where its shoots can mature before the autumn frosts come on. It thrives fairly well in the London parks.

Cultivation.—Even in the milder parts of Southern England the seeds of this tree ripen only in warm seasons; hence a supply is usually obtained from America.

The seeds should be sown as soon as received in autumn, and the plants will come up in the following spring; but if not sown till spring, they will in all probability lie dormant for one year, till the following spring. They should be sown on very light and fine soil or a sandy loam. Or they may be sown in a bed or cool frame, taking care to keep the earth rather moist, and to shade the frame with a thin net till the plants have come up, when the shading should be *gradually* removed. As the seedlings are not well furnished with fibrous roots, they should not be allowed to stand more than one season in the seed-beds before being transplanted into lines to produce fibrous roots. The disposition of the plant to run to a long tap-root instead of ramifying into fibrous roots, makes it difficult to transplant. This inability to bear transplanting, the difficulty it finds in establishing itself, and its slow rate of growth at first, are the main and rather important obstacles in the way of the Tulip-tree ever becoming of true forest growth in Great Britain. Owing to its rapid growth throughout Central and Northern Europe, it is often planted in avenues. The most celebrated of these is one at Wilhelmshöhe, near Cassel (where Napoleon III. was sent after Sedan), consisting of 116 trees.

AMYGDALACEÆ Juss.

18. THE CHERRY, *Prunus* (Linnæan System, Icosandria Monogynia).

Generic Character.—*Drupe* globose, or umbilicate at the base, fleshy, quite glabrous, destitute of bloom, containing a smooth, rather globose compressed stone. *Leaves* simple, alternate, stipulate, deciduous, or evergreen; when young conduplicate. *Flowers* white. *Pedicels* 1-flowered, rising before the leaves, in fascicled umbels, from scaly buds; but sometimes rising after the evolution of the leaves, in racemes, from the tops of the branches (Loudon).

Nearly all the species of this genus are cultivated chiefly for fruit or for ornament; and only one of them, the Wild Cherry-tree or Gean (*P. avium*), is grown as timber.

The majority of the family of the *Amygdalaceæ* chiefly inhabit the warmer temperate and the subtropical zones of the northern hemisphere, although some of them are indigenous to the tropical regions of Asia and Africa. Only three genera are represented in Central Europe — viz., the Almond, the Peach, and the Prunes (Plum, Apricot, and Cherry)—thus distinguishable (Willkomm):—

I. Drupe with tough, leathery pericarp or outer covering, free from sap and finally fissuring irregularly; putamen or interior shell mostly thickened, and with either a smooth, or a pitted, or grooved surface. **Almond** . . . *Amygdalus.*

II. Drupe with thick, fleshy pericarp, which does not dry and fissure; putamen or stone thickened, and covered with a tracery of wrinkled furrows and pitted indentations. **Peach** . . . . *Persica.*

III. Drupe with fleshy or sarcous pericarp, which does not dry and fissure; stone either smooth, or covered with wrinkled furrows, or a shallow network of indentations. **Prunes** . . . . *Prunus.*

The Prune genus is again divisible into three subgenera, viz.:—

1. *Apricots*, having 1 or 2 flowers springing on very short stalks from the side, and a velvety skin to the drupe.
2. *Plums*, having 1 or 2 flowers issuing also from the sides, but on longer stalks having a smooth drupe with a bloom that can be wiped off.
3. *Cherries*, having numerous flowers ranged in racemes or simple corymbs, and smooth, spherical drupes without any bloom.

THE COMMON WILD CHERRY or GEAN, *Prunus avium* L.

SYNONYMS—*P. nigricans* and *P. varia* Ehrh. ; *Cerasus avium* Mönch. ; *C. Duracina* and *Juliana* DC.

Specific Character. — *Flowers* in subsessile umbels, not numerous, white ; May. *Leaves* oval-lanceolate, toothed, glabrous. *Drupe* red ; ripe in July (Loudon).

Distribution.—This species is indigenous throughout the whole of Europe, and eastwards into Asia Minor and the Caucasian districts.

Description.—The Cherry grows wild in our woodlands and hedgerows, where it has a pretty effect in spring when in flower, in summer when in fruit, and in autumn when the leaves turn reddish-yellow. It is distinctly ornamental by the sides of roads running through plantations, as it comes early into flower, when most other trees are only beginning to unfold their buds. It attains a large size, especially when growing along with hardwoods, and trees containing a couple of tons of timber are not rare. In Gloucestershire it is sometimes to be found over 8 ft. in girth.

Economic Value.—Cherry-wood is rather light, but hard. The heartwood is of a beautiful brown or yellowish-brown colour, and takes on a fine polish, which shows up the structure of the timber. Unfortunately it is apt to shrink considerably ; but notwithstanding this it is a favourite wood with furniture and instrument makers, and turners. Stems of good size fetch a fair price, but are seldom to be had.

Soil and Situation.—This tree will grow rapidly on any moderately good dry soil ; but it does best on a deep, rich, light loam. It also grows well on poor limy soil, and forms a clean and straight stem.

Continental experience shows that it attains its best development on a somewhat limy soil, and that it requires at any rate a considerable degree of mineral strength in other classes of land.

Cultivation.—The Cherry is propagated from the well-known seed or stone. The fruits ripen in July, and the seeds should be sown shortly afterwards, as they lose vitality if kept long. It is the parent stock from which the various kinds of yellow, red, and black cherries have been obtained by cultivation, and forms a very good, useful parent stem upon which to graft the nobler species in forming orchards. For this purpose the young stocks are grown from seed.

The Wild Cherry in Woodlands.—It is only a minor tree ; but when grown in close canopy along with other trees, it can rise to a height of close on 70 ft., and be made to form a good, straight, full-wooded stem, with an oval crown of foliage. It does not attain any great age, eighty years being about its normal limit.

In some localities it throws out root-suckers as well as stool-shoots ; but under all circumstances its reproductive power from the stool is good, and it thus manages to maintain itself in coppices and underwoods where the shade thrown by the standards is only light,—for it is not a good shade-bearer.

The Wild Black or Bird Cherry (*Prunus Padus* L.), a close relative of the Wild Cherry, is a beautiful object in parks during spring, when its branches are covered with long hanging racemes of white flowers ; and it also adds considerably to the charm of park scenery during the autumn. It thrives best on fresh or moist land of good quality. It is suitable for mixing in coppice-woods, as it can bear a fair amount of shade, shoots freely from the stool, and often also develops suckers. It is of quick growth, and sometimes attains a height of about 50 ft. Its heartwood is somewhat lighter in colour than that of the Wild Cherry, but otherwise resembles it closely. The bark smells strongly of oil of almonds, owing to the *amygdalin* stored up in it. The leaves and petioles of this species are in every way smaller than those of the Wild Cherry, the two glands on the leaf-stalk of the latter being also more prominent and red; in the former the leaves are naked both above and below, whilst in the latter there is a hairy or woolly growth in the angles of the veins on the lower surface; the drupes of the former are bitter-sweet in taste, black, and not much larger than a pea, whilst those of the latter are rather sweeter, ruddier, and larger.

The Blackthorn or Sloe (*Prunus spinosa* L.) is one of the most charming shrubs in hedges and along country lanes during the early spring, before the woodland trees have done much to change the appearance of the country. The snow-white flowers, which appear before the flush of leaves takes place, are one of the characteristic features of English rural scenery, although even as underwood the Blackthorn can usually only be classed as a weed from a sylvicultural point of view.

POMACEÆ Juss.

The family of the *Pomaceæ* embraces various genera distributed throughout the whole of the temperate and the subtropical zones of the northern hemisphere. It is naturally divisible into two distinct sections—viz., *Pomaceæ putaminiferæ*, having drupaceous fruits; and *P. pomiferæ*, having their fruits in the form of a pome. To the former belongs, along with other genera, the *Cratægus* or Hawthorns, and to the latter the *Pirus* or *Pyrus*, Pears and Apples, and the *Sorbus* or Service-trees, including the Rowan or Mountain-Ash.

19. THE HAWTHORN, *Cratægus*
(LINNÆAN SYSTEM, ICOSANDRIA DIPENTAGYNIA).

Generic Character.—*Calyx* with an urceolate tube, and a 5-cleft limb. *Petals* orbicular, spreading. *Ovarium* 2-5-celled. *Styles* 2-5, glabrous. *Pome* fleshy, ovate, closed; the calycine teeth, or the thickened disk, containing a bony putamen (Loudon).

There are many species and varieties of the genus *Cratægus*;[1] they are chiefly deciduous small trees or large shrubs, and only a few of them grow to 30 ft. in height. Most of the species are natives of North America and Central Asia, and only a few belong to Europe. All are easy to grow, flower profusely, and are very ornamental. Reference need only be made to one member of this family, the Common Hawthorn (*C. Oxyacantha*).

THE COMMON HAWTHORN, THORN, QUICK, or HAWTREE,
Cratægus Oxyacantha L.

SYNONYMS—*C. semitrigyna* Wierzb.; *C. macrocarpa* Hegetschw.; *Mespilus Oxyacantha* Willd.

Specific Character.—*Leaves* obovate-wedge-shaped, almost entire, or trifid or cut, glabrous, rather glossy. *Flowers* white, in corymbs of several flowers; May. Sepals glandless, acute. Styles 1-3. *Haws* red or scarlet; ripe in September (Loudon).

Distribution.—The Common Hawthorn is, together with a very closely allied form, *C. monogyna* (Jacquin), found in most parts of Europe, but is more frequent in the

[1] Although somewhat slow in growth, most hawthorns have a strong power of shooting from adventitious buds on the branches as well as from the stools; hence their special value for hedging purposes. They form a very hard wood, but have little value as coppice, owing to their slow growth and small size. Otherwise they would be suitable for underwood, as they can bear a considerable amount of shade.

northern than the southern portion of the Continent, where the latter species is more abundant. Our Hawthorn is distinguishable from *C. monogyna* by being of a yellowish-green colour on the under surface of the leaves, those of the latter being bluish-green; and it has the secondary nerves curved inwards (or at least the lower nerves are always inclined inwards), whilst in the latter they are curved outwards (at any rate in the case of the lower nerves). Both of these species also occur throughout Eastern Europe, whence they extend eastwards into Central Asia, as well as southwards to Syria and Northern Africa.

Description.—The Hawthorn cannot be considered a timber-tree, but merely an ornamental shrub, capable of being trained (by pruning) to the size of a small tree. Its main use is for the formation of live or quick hedges, for which purpose no other plant is so suitable. It grows in a great variety of soil, forms a thick hedge, and resists pressure when properly trained for the purpose. On a dry loamy soil it grows freely and rapidly till about fifteen years of age, but after it reaches about 15 to 20 ft. high its growth in height ceases, its crown of foliage expands, and it assumes the character of a large and spreading bush. Once it has arrived at this state, it annually produces masses of sweet-smelling flowers, "May-blossom," in spring, which turn into bright-red "haws" before the autumn. The flowers are pinkish-white; but there is also a beautiful variety called *C. O. rosea*, which has petals of a bright-pink colour, with white claws. When both kinds are planted near each other, they form a charming contrast.

Economic Value.—The wood of the Common Hawthorn is yellowish-white and very hard. It is finely grained, and takes on a good polish; but it is generally too small in size to be of much use. It makes good firewood.

Soil and Situation.—Hawthorn does not grow well on wet, or on poor, light soil. It does better on a heavy, dry loam, even if rather stiff; but it thrives best on limy and marly soil, and good, dry loam. So long as the soil is suitable, it is a very hardy plant,—one of our hardiest.

Cultivation.—Varieties are propagated by budding or grafting on stocks of the Common Hawthorn, raised from seed. Haws are produced in large numbers during warm seasons, and are fit for gathering and sowing early in November.

When collected from the bushes, the haws should be laid on the ground in a heap about 2 ft. high and 4 ft. broad at base, in order to rot the pulp and separate it from the stones. To prevent the pulp from heating and spoiling the seed, it is well to mix finely riddled soil bulk for bulk with the haws themselves, the whole being well mixed together, so as to hasten the decomposition of the pulp. This heap should be turned over about once a-fortnight, and allowed to lie for fifteen or sixteen months, when the pulp will be quite rotted, and the seed ready for sowing. Thus haws gathered and treated in this manner during November 1904 would be ready for sowing in February 1906.

The clean seeds should be sown in beds on a good light mould. They should be sown rather thinly, say at the rate of one seed to the square inch, and covered with from about $\frac{1}{4}$ to $\frac{1}{2}$ an inch of earth. They will come up the same year, but should not be lifted till they have stood two years in the seed-bed, when they should be transplanted into nursery-rows 1 ft. apart, and at a distance of about 2 in. from plant to plant. After standing for two years in the nursery-beds they will be fit for hedging or other purposes.

The Continental plan is to sow the haws, immediately after they ripen in autumn, in a limy or marly soil, marl being added to the seed-beds if the soil of the nursery is deficient in lime. Sometimes germination takes place in the following spring, but usually not until the second spring after the sowing. The drills are made about 4 in. broad and 8 in. apart, and the haws are covered with about $\frac{3}{4}$ of an inch of earth. In order to keep the soil warm, and thus stimulate germination, the seed-beds are covered with Pine sprays or dead leaves, which may be removed from time to time to see if germination has begun. Without such a warm covering, germination does not take place till the second spring. When once the seedlings are two-year-old, their tap-roots are shortened and they are transplanted into the nursery-beds, and then put out two years later for forming hedges.

20. THE MOUNTAIN-ASH, *Sorbus*
(LINNÆAN SYSTEM, ICOSANDRIA DIPENTAGYNIA).

Generic Character.—*Calyx* with an urceolate tube, and a 5-lobed limb. *Petals* roundish, spreading, flat. *Styles* 2-5. *Pome* closed, 5-celled, globose, or top-shaped. *Seeds* 2 in each cell. *Testa* cartilaginous. *Leaves* imparipinnate, or pinnately cut. *Flowers* in branched corymbs (Loudon).

The genus *Sorbus* is closely related to that of *Pirus* or *Pyrus*, which comprises our British fruits, pears and apples. Both differ from the other European genera of the *Pomaceæ* (*Cotoneaster*, *Mespilus*, and *Cratægus*) by having pomes as fruits in place of drupes, a difference which they share with the genera *Cydonia* and *Amelanchier*. But the only genus and species of these *Pomaceæ* to which reference need here be made is the Rowan or Mountain-Ash (of the *P. pomiferæ*), one of the most beautiful of our indigenous trees. It is a handsome small tree in our woods at all seasons of the year, and is perhaps better known by its local names of *Rowan-tree* in Scotland and *Witchen-tree* in England, than by the rather misleading name of Mountain-Ash.

Apart from botanical differences, this tree can easily be distinguished from any of its close relatives, the Pears and Apples, through the foliage alone. In the latter (*Pirus* or *Pyrus*) the leaves are always simple and undivided; in the former (*Sorbus*) the leaves are simple, and entire or pinnatifid, or less frequently imparipinnate (as in the Rowan).

COMMON MOUNTAIN-ASH, ROWAN, or FOWLER'S SERVICE TREE, *Sorbus Aucuparia* L.

SYNONYMS—*Pyrus Aucuparia* Gärtn.; *Mespilus Aucuparia* Scop.

Specific Character.—*Buds* softly tomentose. *Leaflets* serrated, slightly glabrous. *Pomes* globose. *Flowers* white; May. *Fruit* red; ripe in September (Loudon).

Distribution.—The Common Rowan or Mountain-Ash is one of the most widely distributed of trees, being found from the sea-level up to near the limit of eternal snow. It is a native of most parts of Europe, from Iceland to the Mediterranean. It also extends throughout the whole of North-western Asia, and occurs in the northern parts of North America. It is indigenous to Britain, and is common in our woods and hedges all over the country, where it is generally to be found growing on moist soil, resting on stiff subsoil. It is a very characteristic tree of the Scottish Highlands.

Description.—The Mountain-Ash is in summer distinguishable from all the other species of the same genus by its *pinnate* leaves, which resemble those of the Common Ash, and in autumn by its beautiful coppery-red foliage and its bunches of bright-red berries. It is not really a timber-tree, as even on good land it only attains a height of about 30 to 40 ft., with a stem up to about 2 ft. in diameter, which bears an oval crown of rather sparse foliage. But it can sometimes be of use as a nurse for hardwoods in small plantations or narrow beltings (where Pine and Larch would be apt to overgrow and suppress them), as it never overtops other trees growing with it, but leaves them sufficient growing-space for the development of their crown.

Economic Value.—Its wood is of a reddish-brown colour, and a soft and fine texture; it is highly prized for cart-making and for agricultural implements, owing to its extreme toughness. It is suitable for coppicing, as in addition to reproducing itself well from the stool, its long branching side-roots throw up suckers freely. The suckers and stool-shoots grow into strong rods within four or five years after being coppiced, and they are useful for hoops, crates, and rough basket-work.

Soil and Situation.—The Mountain-Ash is the hardiest of all our British forest-trees; and it is the best endowed with accommodative power in respect to soil and situation. To these natural capacities, to its power of reproducing itself from stoles, and to the distribution of seed by means of birds, are due its remarkably extensive distribution, both horizontally and vertically; for the pome, though not heavy, is not apt to be carried far from the parent trees by the wind. But, though it will grow on poor soil and in exposed situations, wherever it is wanted for ornament it should be grown on a good soil, and in a somewhat sheltered though not confined situation. The proper locality for it is along the sides of roads in plantations: here it grows rapidly, soon develops a crown of moderate size, and shows well against other trees, especially in the autumn, when its foliage is changing colour and its fruit is in perfection.

Ebermayer's investigations have proved that Rowan makes considerable demands on the soil with respect to mineral food, being classifiable between the Elm and Lime on the one hand, and the Acacia and Horse-Chestnut on the other. And it also makes considerable demands on soil-moisture, being in this respect on about the same level as the Birch and the Sycamore. These scientific results may appear to be in conflict with our common experience that Rowan is often found of good spontaneous growth on poor shallow soil, until the large development of widespreading surface-roots is taken into consideration.

Cultivation.—The fruit should be gathered as soon as it ripens in September, for birds soon devour it. After it is gathered, the seed should be prepared like haws (see p. 183). Both Rowan and Hawthorn lie about eighteen months in the earth before germinating; but when rotted in a heap, or mixed with earth for about fifteen months, and then sown after all the fleshy pulp is decomposed, they come up in the following June. Rowan-seed should be sown thinly, say 4 sq. in. for each seed (2 by 2), because the leaves are comparatively large, and thickly-sown seedlings would be crowded and drawn up. As it is of rapid growth, the seedlings may be transplanted into the nursery-lines during the autumn of the first year, by which time they will generally have a height of 8 to 12 in. In the nursery-lines they should be put in about 3 in. apart, with 18 in. between the rows. After one year there, they will usually be about 3 ft. in height on the average, and fit for planting for ornamental purposes.

The Service Tree (*Sorbus torminalis*, Crantz. Synonyms: *Cratægus torminalis* L.; *Pyrus torminalis* Ehrh.) is an old-fashioned tree, which was probably indigenous to Central and Southern England, and commonly of true woodland growth formerly (as it still apparently is in the Lord Bathurst's woods, Cirencester, Gloucestershire); but now it is usually only to be found in quaint old gardens and in parks.

Like the Rowan, it is only a minor tree, attaining under favourable conditions a height of about 60 ft.; but it forms a somewhat rounder and more densely-foliaged crown than the former. Its stem is covered with greyish-brown bark, furrowed by long fissures, between which the bark flakes off in patches here and there. Its foliage is an object of beauty in the autumn landscape; but its hue is golden, and contrasts well with the coppery sheen of the Mountain-Ash. It also differs greatly from the latter as to its demands regarding soil and situation; for it does not grow well on sand, but requires soil of considerable mineral strength, and certainly thrives best, like the Yew and the Holly, on land of a limy description.

Another species of Service (*S. domestica*) formerly grew wild in Central England, but is now only to be found where planted. It sometimes attains large size, and then yields a very beautiful, wave-lined timber. It is a very suitable fruit-tree for old-fashioned gardens, but is of an almost purely ornamental character. It is cultivated as a fruit-tree in some parts of France, where it is known as "le cormier"; and it can easily be obtained from French nurseries. Its wood is brownish-yellow at first, but deepens later on into ruddy-brown, speckled with numerous short medullary rays. It is specially prized by turners and cabinet-makers, as it is denser in the grain and heavier (0·80) than Pear-tree (0·73) when seasoned ; and it is often sold as **Boxwood,** in the shape of surveyors' scales, &c.

It is a low-growing tree, which lives to over 100 years. Although it can bear a good deal of shade, yet its slow growth has doubtless caused it to be gradually ousted from the woodlands. As its fruit is rather heavy, the seeds could not be wafted far from the parent trees by the wind ; and as it is at the same time large, it could not conveniently be distributed naturally by means of any of our numerous small birds that convey the Rowan-seed far and wide.

PAPILIONACEÆ L.

The Papilionaceous division of the great order of *Leguminosæ* embraces a considerable number of sub-families and genera. To it belongs the family of *Genisteæ*, including Furze, Greenwood, and Broom, shrubs occurring throughout Britain only too frequently in the undisturbed possession of land that might be far more profitably utilised for growing crops of timber.

Apart from some flowering shrubs of horticultural importance, the only genera of arboricultural or sylvicultural interest are the Laburnum (*Cytisus*) and the False Acacia (*Robinia*).

21. THE LABURNUM, *Laburnum* (Linnæan System, Monadelphia Decandria).

Generic Character.—*Calyx* bilabiate. *Upper lip* usually entire ; lower one somewhat tridentate. *Vexillum* ovate, large. *Carina* very obtuse, including the stamens and pistils. *Stamens* monadelphous. *Legume* compressed, many-seeded, glandless. *Leaves* trifoliolate, alternate, stipulate. Flowers of nearly all the species yellow (Loudon).

The *Cytisus* forms a group of ornamental trees and shrubs, of which only the **Laburnum** genus need be referred to here. They are hardy trees, suitable for ornamenting the sides of roads in our woods. There are five species of the *Laburnum* DC. throughout Central Europe, but only two of these possess any real interest for Britain—the Common Laburnum (*L. vulgare*) and the Scots Laburnum (*L. alpinum*). But these are so very much alike that they may conveniently be classed together as if one species. They have the same general appearance, are equally hardy, are of the same habit of growth, and are cultivated in the same way.

THE COMMON LABURNUM, *Laburnum vulgare* Gris. Rchb. (Synonym—*Cytisus Laburnum* L.), and THE SCOTS LABURNUM, *Laburnum alpinum* Gris. Rchb. (Synonym—*Cytisus alpinus* Mill.)

Specific Characters.—Common Laburnum (*Laburnum vulgare*)—*Branches* terete, whitish. *Leaves* petiolate ; leaflets ovate-lanceolate, pubescent beneath. Racemes pendulous, simple. Pedicels and calyxes clothed with closely pressed pubescence. *Legume* linear, many-seeded, clothed with closely pressed pubescence. Scots Laburnum (*L. alpinum*)—*Branches* glabrous and terete. *Leaves* petiolate ; leaflets ovate-lanceolate, rounded at the base. Racemes pendulous. Pedicels and calyxes puberulous. *Legumes* glabrous, few-seeded, marginate (Loudon).

Distribution.—The Laburnum grows spontaneously in the mountain forests of Germany, Austria, Hungary, Switzerland, Italy, Eastern France, and Spain. It was introduced into Britain about 1596.

Description.—It seldom grows to any great height or girth. But in June or July its small, shining, bright-green foliage—a trefoil on each petiole—and its pendulous clusters of bright-golden flowers, make it one of the most attractive objects in parks, shrubberies, and gardens. And, of course, to produce these in perfection, the trees must have abundance of light and air; without plenty of growing-space, it loses greatly in picturesque effect. But its flowering lasts longest when other trees protect it from the direct rays of the sun.

Out of several varieties of the Common Laburnum two are largely cultivated by horticulturists. Of these the var. *quercifolium* has wavy-lined or lobed leaflets, whilst in the var. *Alschingeri* the racemes are upright instead of pendulous, and the vexillum of the flower is marked with a broad brown line.

Economic Value.—The wood is hard, the sapwood yellow, and the heartwood blackish-brown in colour. It takes a fine polish, resembles ebony in appearance and texture, and is valuable for cabinetmaking. Good-sized stems will fetch as much as 7s. a cubic ft. for this purpose.

Soil and Situation.—Laburnum will grow in most soils; but it requires a deep, loamy, and rather light dry soil and a well-sheltered situation to enable it to grow to any large size. For timber, it should be planted on a strong soil; but if for ornament merely, it may be planted wherever it is wanted.

Cultivation.—The seed of the Laburnum is of a very poisonous nature. It generally ripens in October, when the seed-pods should be gathered and stored in a dry, airy loft until required for sowing towards the end of March. The seed should be thinly sown in beds of light soil, and should not be covered with more than half an inch of earth. As Laburnum grows rapidly when young, the seedlings should during the following spring be transplanted into the nursery-lines and treated like the Mountain-Ash (see p. 185).

22. THE FALSE ACACIA, *Robinia*
(Linnæan System, Diadelphia Decandria).

Generic Character.—*Calyx* 5-toothed, lanceolate, 2 upper ones shorter and approximate. *Corolla* papilionaceous. *Vexillum* large. *Keel* obtuse. *Stamens* diadelphous, deciduous. Ovaries 16-20-ovulate. *Style* bearded in front. *Legume* compressed, almost sessile, many-seeded, with the valves thin and flat, marginated at the seminiferous suture. *Leaves* compound, unequally pinnate, alternate, deciduous; leaflets generally ovate or obovate, petiolate. *Flowers* white or rose-coloured, in axillary usually nodding racemes (Loudon).

Only one species of this genus of Asiatic and American trees and shrubs need here be referred to—the Common Robinia, or False Acacia (*R. Pseudacacia*). It is a rapid-growing tree, with beautiful, fine, pinnated leaves, and pendulous, white, sweet-smelling flowers. This is in all respects a desirable tree for ornamenting lawns and shrubberies, besides possessing fair claims entitling it to a certain amount of purely sylvicultural attention.

THE ROBINIA or FALSE ACACIA, *Robinia Pseudacacia* L.

Specific Character.—Prickles stipular. *Branches* twiggy. Racemes of flowers loose and pendulous; and smooth, as are the legumes. Leaflets ovate. *Flowers* white and sweet-scented; May and June. Roots creeping, and their fibres sometimes bearing tubercles. *Legume* compressed, dark purplish-brown; ripe in September (Loudon).

Distribution.—This tree is a native of North America, whence it was introduced from Virginia into Britain by Robin in 1638. It is found in the forests of Canada and the Northern States of the Union, generally growing singly among other trees, or in small groups, and always on dry land of good quality. It is much cultivated in America, both for timber and for ornament, under the name of the "Locust-tree." It is quite hardy in most parts of Britain. In the warmer and milder portions of the country it attains a considerable size, and forms a highly ornamental tree, that gives a peculiar effect to the landscape by its beautiful pinnated leaves and its pendulous bunches of pinkish-white flowers, which it begins to bear in profusion from about its twentieth year onwards.

Throughout the arboreta and public parks of Central Europe, with the exception of Northern Prussia, where the climate is too cold in winter for this genus, two ornamental species of the Robinia are extensively cultivated on account of their beauty—viz., the Red Acacia (*R. hispida* L.), a low-growing tree with small stipular thorns or spines and large rose-coloured flowers, and the sticky Robinia (*R. viscosa* Vent.), a smaller tree with sticky leaves and roundish clusters or close racemes of reddish-white flowers. Both of these species have likewise been introduced from North America (Willkomm).

Description.—In the North American woods the Robinia grows to 70 or 80 ft. high, and 2 ft. in diameter, when drawn up along with Walnuts, Limes, and Maples. But otherwise it only reaches about 30 to 40 ft. in height, and forms a short irregular stem about 3 ft. in diameter. It is a tree that seems worthy of more attention—arboricultural, at any rate—than has yet been paid to it in Britain. Although its timber is good, many other trees can be grown extensively with better chance of profit, so that it is chiefly as an ornamental tree that it may be strongly recommended for planting on lawns or along the edge of plantations. Here its fine, thin foliage—each imparipinnate leaf with eleven to twenty-one leaflets — and its beautiful pendulous racemes of scented white flowers are a distinct addition to the landscape. The branches of young trees are armed with strong hooked prickles, which disappear from old trees. It grows rapidly in height at first, but soon begins to spread out horizontally, like Mountain-Ash and Laburnum. It has been largely planted along the streets of Montreal, in Canada; but, though otherwise suitable, in this climate it comes into leaf too late in spring and sheds its foliage too early in autumn to be so generally suitable as Plane-tree or Elm for town planting.

Economic Value.—The wood of the Robinia is greenish-white, but soon gradually turns to reddish-yellow in the heartwood. It is porous and easy to work, though apt to cause sores, owing to some poisonous secretion contained in it. With the exception of the Conifers, it is the most elastic of the woods grown in Europe; and with the exception of shrubs like Dogwood, Hawthorn, and Sloe, it has the hardest wood, although not belonging to the heaviest class of timber. It has a sp. gr. of 0·87 when green and 0·73 when seasoned, so that it is lighter than the Oak, Ash, or Maple, but heavier than Elm, Chestnut, Sycamore, or Birch. It belongs to the most durable class of timber, and under favourable conditions may even rank before the Oak in this respect. In America it is used for fencing, housebuilding, and furniture. On the Continent it is extensively used for cart-making, for agricultural implements, and for props for training up the vines in vineyards. A very important and remunerative use of the wood is the manufacture of long wooden nails or pegs for shipbuilding, for which an unusual degree of elasticity and toughness makes it especially valuable.

Soil and Situation.—In the American woods Robinia for the most part grows on deep, light, dry, and moderately rich land. In Canada, especially in the neighbourhood of Ottawa, it has been found to grow well on poor sandy soil exhausted and unfit for the profitable cultivation of farm crops. In Britain it grows well on most lands that are neither wet nor stiff; but it does best on a sheltered though not confined situation, for it cannot thrive unless freely exposed to the rays of the sun.

Cultivation.—The seed of Robinia ripens well in England, and sometimes in Scotland; but supplies are often obtained direct from America. It should be kept in the pod till sown, else it loses vitality, and much of it will consequently fail to germinate. The American seed has better germinative power than that gathered from home-grown trees.

Early in spring, during good weather about the end of February or early in March, the seed should be sown at a distance of about 3 in., in rows about 15 in. apart. The soil should be light, rich, and well prepared, and the covering of earth may be fully half an inch. The seedlings appear during the summer, and are fit for transplanting into nursery-rows in the following spring, at a distance of 4 in. from plant to plant, the rows being not less than 20 in. apart. When they have stood for one year in the nursery-lines they will be about 3 ft. high, and ready for planting out into their permanent sites. No difficulties whatever are connected with transplanting; for no other tree, when transplanted, establishes itself more readily and easily. In Germany the seed is collected in bags and threshed out of the pods. It germinates about fourteen days after being sown in spring. As the Robinia seeds there freely every year, it is seldom necessary to store the seed; but Continental seed is there found to retain its germinative power for several years. On very light soil, yearling seedling-plants are put out by the simple method of notching, but in other cases two-year-old plants are used generally.

Sylvicultural Characteristics.—The False Acacia is a very interesting tree, for whilst, as above stated, it can thrive on very poor land, yet, as a matter of fact (proved by Ramann's investigations and Ebermayer's analyses), it withdraws very considerable quantities of mineral food and of moisture from the soil. With respect to the food-supplies annually withdrawn from the soil, it ranks next after Ash, Italian Poplar, Elm, Lime, and Rowan, and comes before Horse-Chestnut, Sycamore, Maple, Aspen, Willow, Oak, Silver Poplar, Hornbeam, Beech, White Alder, Birch, and Common Alder, in which order the deciduous trees are classed by Ebermayer. With respect to demands for soil-moisture (for transpiration), it ranks next to Italian Poplar, Horse-Chestnut, Ash, and Common Alder, and comes before Oak, White Alder, Elm, Lime, Birch, Rowan, Sycamore, Willows in general, Maple, Aspen, Beech, Hornbeam, and Silver Poplar. Sylviculturally, therefore, it occupies a paradoxical position, like that which the variety of pulse called Lupine occupies agriculturally; for whilst analyses of its foliage and stem show that it withdraws from the soil large amounts of mineral salts, and of the water in which they are held in solution, yet it apparently is content even with occupying poor sandy soils. But both with regard to the Robinia (which is assisted in this matter by its extensive horizontal root-system) and the Lupine, this mysterious paradox was solved by the discovery that a fungus (*Bacillus radicicola* or *Rhizobium leguminosarum*) lends symbiotic aid in the formation of nitrogenous and albuminoid substances, which are stored up in the tubercles or nodules on the roots, and within which the *Bacteria* are located. The Common Alder is also similarly assisted by a bacterial symbiosis on land of poor quality.

As a considerable degree of warmth is requisite for the Robinia, its cultivation on any large scale could probably only prove successful in the milder tracts of England. It is liable to be damaged by late frosts in spring, and heavy winds are apt to tear off the branches; hence it requires to occupy a sheltered position. Notwithstanding its very extensive superficial expansion of roots (which can often be of great service in binding light sand), it throws down a deep tap-root into the soil; and like all trees developing a strong tap-root, it makes a considerable demand for light and air, and therefore requires a large amount of growing-space for the unhindered development of its expansive, lightly foliaged, and irregular crown. It is well adapted for planting along the slopes of steep railway cuttings or embankments with a view to fixing the soil, and for fringing, along with the Birch, tracts of Scots Pine-woods through which lines of railway pass, and where there is a constant danger of the soil-covering of dead needles being set fire to by the sparks of locomotives during the hot dry months of July and August.

The Robinia does not grow to large dimensions as timber in England, although in Central and Southern Germany, where it is often grown in pure clumps on warm situations, it reaches nearly 80 ft. in height and over 2½ ft. in diameter. But it is as coppice that it seems to have the fairest chance of being profitable, because it possesses strong reproductive capacity both by means of root-suckers and stool-shoots. For underwood, however, it is altogether unsuitable, owing to its being a very pronounced *light-demanding* species. It is very liable to be damaged by hares and rabbits; but where these can be kept off it will, when intermixed with less quickly growing trees, yield a very fair return in coppice-woods worked with any rotation from ten to twenty-five years. Its long, straight, and very durable poles make good hop-poles; whilst with a low rotation it yields good withes and tough hoops for casks. It is well adapted as a standard in copse, as it throws only a light shade over the underwood. It then yields its best profit between forty and sixty years of age, when it attains full maturity as a tree. For warm sandy land in Southern England, like the Pine tracts of Hants and Surrey, the growing of Acacia seems to offer a fair chance of profit within a reasonable time.

ILICINEÆ Brongn.

The various genera forming the family of *Ilicineæ* are mostly scattered throughout South Africa, the West Indies, and South America, while only a few are indigenous to Europe. Along with the families of the Pimpernels (*Staphyleaceæ*), the Spindelwoods (*Celastrineæ*), and the Dogwoods (*Rhamnaceæ*), they form the natural order of *Frangulinæ* as represented throughout Central Europe.

23. THE HOLLY, *Ilex* (Linnæan System, Tetrandria Tetragynia).

Generic Character.—*Calyx* 4-5-toothed, permanent. *Corolla* 4-5-cleft, subrotate. *Stamens* 4-5, alternating with the segments of the corolla. *Ovary* sessile. *Stigmas* 4. *Berry* containing 4-5 one-seeded nuts (Loudon).

There are several species and varieties of this genus, some with spiny teeth on their leaves and others without, mostly evergreen shrubs or low trees, natives chiefly of Central Europe and North America. The only species that need here be referred to is the Common Holly (*Ilex Aquifolium*).

THE COMMON HOLLY or HOLM, *Ilex Aquifolium* L.

Specific Character.—*Leaves* oblong, shining, wavy, spiny-toothed. Peduncles axillary. *Flowers* nearly umbellate, white; May. *Fruit* red; ripe in September, and remaining on the tree all the winter. The lower leaves are very spinous, while the upper ones, especially on old trees, and sometimes even from a height of only about 4 ft., are entire—a peculiarity shared to some extent by the Evergreen Oak. Bushes that have been grazed on by cattle or goats, or that have been pruned (as in hedges), have more and larger spines than those left in a true state of natural growth.

Distribution.—The Holly is indigenous to most parts of Central and Southern Europe, and is frequently to be found of spontaneous growth in woodlands. It is plentiful in most of the old copsewoods throughout Great Britain and Ireland, and is especially abundant in Hants and the neighbouring counties.

Description.—The Holly is capable of bearing a considerable amount of shade, but it only attains the height of a tree when growing in full exposure to light and warmth. When merely of spontaneous growth it is seldom more than 20 ft. in height, while in the cultivated state it attains upwards of 60 ft., and may even contain a fair quantity of timber in its stem. But it is grown almost exclusively for its ornamental effect. It is beautiful at all seasons of the year, but more especially in winter, when its glossy, dark, evergreen foliage and its clusters of bright-red berries are seen at their very finest.

Along with the Yew, it forms one of the best of our native evergreen hedges. When growing as a tree, its crown assumes a conical shape ; and as, owing to the numerous adventitious buds which it develops, it has a strong reproductive power, it stands cutting and trimming well. This latter capacity was utilised to a great degree in old-fashioned gardening, the shrubs often being made to assume fantastic shapes. Holly attains a great age : many trees are known to be several hundred years old. One of the largest-girthed specimens of Holly is probably that in Col. Lloyd-Verney's grounds in Llanidloes, Montgomeryshire, which has a circumference of 30 ft. and a height of 43 ft.

For ornamental purposes several varieties are propagated, of which the chief are the white-and-yellow foliaged kind (var. *variegatum*), the prickly leaved kind (var. *ferox*), and the smooth, entire-edged kind (var. *inerme*). These varieties are extensively cultivated in gardens throughout Britain and Central Europe.

Economic Value.—The wood is of a dull greenish-white colour, hard, heavy, tough, and of a fine and equal texture, with plainly marked annual rings and fine medullary rays. In technical qualities and value its wood closely resembles that of the Yew. Any really large Holly-tree may be readily disposed of to cabinetmakers at a good price. The wood is used for inlaying, and also to some small extent by turners and engineers. Formerly good stems used to fetch about £6 a-ton, but there is no market for small stuff.

Soil and Situation.—The Holly thrives best on a light, dry, humose loam. Fair specimens of it, and of its varieties, may often be found on heavy soil as well as on poor land ; but really healthy, thriving bushes are seldom to be found except where the soil contains a good deal of vegetable-mould, as in old woodlands. It often occurs of spontaneous growth in cool, shady spots on fresh, loamy, sandy, or limy soil—for, like the Yew, a certain amount of lime in the soil seems to favour its growth. On good classes of land it may sometimes be troublesome as a weed during natural regeneration of a highwood crop.

Like Hawthorn and Hornbeam, Holly is largely used for hedging. Few shrubs are really so well fitted for quick hedges, for it is evergreen and forms an excellent fence ; and besides affording shelter, its appearance is at all times good. Although very hardy, and sometimes growing to a fair size on poor and exposed sites, yet it needs a certain amount of shelter before it can thrive really well.

Cultivation.—The Holly is always grown from seed, but the several varieties of it are propagated by budding and grafting, and sometimes by slips or cuttings. The mode of gathering, preparing, and sowing the seed is the same as described for the Hawthorn (see p. 183).[1] It possesses considerable reproductive power in shooting

[1] The seeds of both require about eighteen months to germinate : hence if the seed be sown when it ripens in autumn, it will usually lie dormant for a year and a half in the ground before it comes up ; but when stored either in or out of the ground, and not sown for sixteen months after collection, it comes up during the spring when sown. Holly is of slow growth when young, so that the transplanted seedlings should stand for three years in the nursery before planting them out permanently. By that time they form good fibrous roots, and develop into strong plants ; and these are points of importance in hedge-planting.

When plants of large size are wanted, the transplants should be allowed to stand four from the stool, and is often to be found cropping up in coppice-woods; but when the period of rotation extends beyond about ten years, it gradually disappears from the woods, as it is of slow growth, and gets suppressed by more rapidly growing species.

SIMARUBACEÆ.

24. THE TREE OF THE GODS or TREE OF HEAVEN, *Aïlanthus glandulosa.*

Specific Character.—*Leaves* paripinnate, single, large (up to 32 in. long), have 1 to 3 glands on either side at the base of the large-pointed ovolanceolate leaflets,—and these glands are sufficient to distinguish the tree from any other cultivated here. *Flowers* small, polygamous, greenish, in large terminal clusters. *Fruits* winged on each side, 2 in. long, red at first, then turning brown.

Distribution.—It is a native of China.

Description, &c.—This tree is often planted in sheltered situations in parks and avenues. It grows very rapidly (often over 3 ft. a-year for the first five or six years), but only lives for about forty to fifty years. It grows well on any deep, dry, porous soil, but is apt to suffer from late frosts. It has a very strong reproductive capacity from both stool and roots. It ripens seed in England, and is said to produce good timber. But our climate is not warm enough for it to be of other than merely arboricultural interest. It does fairly well in the London parks along with the Tulip tree, the Japanese Maidenhair tree, and the quick-growing Indian Bean or *Catalpa.*

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or five years in the nursery-lines, each alternate plant being removed in order to give the remaining ones room to develop. Holly plants of any age, from seedlings upwards, always suffer to a greater or less extent if transplanted when the atmosphere is at all dry; hence care should be taken to transplant only during wet weather. It is well to move seedlings from the seed-bed to the nursery-lines in wet weather about the end of April; and even though the weather be damp or wet, no harm is done by giving the roots a thorough watering, after the first spadeful of earth is put on them. This assists the plants to establish themselves in their new environment; for if they lack moisture they soon wilt, and many are certain to die off.

CHAPTER II.

CONCERNING CONIFEROUS OR NEEDLE-LEAVED TREES.

A—CONIFERÆ Juss.

The Scots Pine and the Common Juniper are the only two species of *coniferous* trees indigenous to Britain, though the very closely related *pseudodrupaceous* (non-coniferous) Yew is also a native of these islands. All of these three trees are evergreen, and all of them have more or less needle-shaped foliage, quite unlike that produced on broad-leaved trees. The natural order of the *Coniferæ* may be divided into the following four tribes or groups :—

I. **Araucarieæ.**—Andrœceum (or male organs) with 6 to 20 anthers. Cone-bracts arranged spirally ; outer scale (bract) and seed-scale united, or only separate at the apex. Ovule single, inverted, and attached longitudinally to the scale. Cone large, upright, and woody : the seed ripens only in the second autumn after flowering.

Diœcious evergreen trees having regular branch-whorls and naked buds.

II. **Abietineæ.**—Anther scales with 2 anthers. Cone-bracts arranged spirally ; outer scale (bract) and seed-scale separate, or only united near the base. Ovules dependent, 2 being situated at the base of each scale. Cones woody : in some cases the seeds ripen during the year of flowering, in others not till the second year.

Monœcious and mostly evergreen trees and shrubs, whose branches usually develop in regular whorls, and whose buds are usually naked.

III. **Cupressineæ.**—Anther scales with 3 to 6, and only seldom 2 anthers. Cone-bracts, 4 or numerous, ranged crosswise, singly, or in clusters of 3 or 4 ; outer bract and seed-scale indistinguishably united. Gemmula upright, with 2 or numerous ovules on each bract. Cones small in size, and either woody or having a pulpy sarcous development like a berry.

Monœcious and diœcious trees and shrubs, mostly evergreen, with branches ranged irregularly round the central axis, and having naked buds.

IV. **Taxodineæ.**—Anther scales with 2 to 5 and seldom 9 anthers. Cone-bracts arranged spirally : outer scale (bract) and seed-scale united to form 1 bract, but still plainly distinguishable. Ovules 3 to 9, less frequently only 2, and sometimes only 1 ; sometimes upright on the seed-scale, sometimes reflexed or even inverted. Cones woody : in some cases the seeds ripen in the year of flowering, in others not until the second year.

Trees either monœcious or diœcious, mostly evergreen, whose branches sometimes develop in whorls, and sometimes only irregularly around the central axis, and whose buds are naked.

The various genera of these four tribes that are of importance in Britain are the following :—

I. **Araucarieæ :** 1. *Araucaria.*

II. **Abietineæ :** 1. *Pinus*, 2. *Picea*, 3. *Tsuga*, 4. *Pseudotsuga*, 5. *Abies*, 6. *Larix*, 7. *Cedrus.*

III. **Cupressineæ**: 1. *Cupressus*, 2. *Chamæcyparis*, 3. *Thuja*, 4. *Biota*, 5. *Libocedrus*, 6. *Juniperus*.

IV. **Taxodineæ**: 1. *Cryptomeria*, 2. *Sequoia*, 3. *Taxodium*.

For convenience, the *Taxus* or Yew will also be considered along with the Conifers, after all these various genera have been dealt with; but as its fruit is a *pseudodrupe* or false berry—and not a true cone—it has now been formed into a separate family, *Taxaceæ* Lindl., the only family of the natural order *Pseudodrupaceæ* Willk.

I. *ARAUCARIEÆ.*

No genus of this tribe is indigenous to Europe. All belong to the tropical and subtropical zones of the southern hemisphere. It is one of the smallest of all the natural families of trees, as it consists of only one genus, *Araucaria*, of which two species, the Chili Pine (*A. imbricata*) and the Norfolk Island Pine (*A. excelsa*), have been introduced into Britain for ornament.

1. THE ARAUCARIA OR PUZZLE-MONKEY, *Araucaria* (LINNÆAN SYSTEM, DIŒCIA MONADELPHIA).

Generic Character.—Lofty trees. Flowers diœcious; males in spikes; anther-lobes 8-15, pendulous; pollen globose. Cones globular, scales very numerous, spiral, deciduous, united with the bracts. Ovule 1 to each scale, more or less winged, inverted, and more or less united with the scale itself. Cotyledons epi- or hypogeal.[1]

(1) THE CHILI PINE, *Araucaria imbricata* Pav.

Specific Character.—*Leaves* in whorls of from seven to eight in number, ovate-lanceolate, spirally placed, rigid, concave, straight, smooth, shining, deep-green, very pungent, closely *imbricated* or placed so as to overlap each other like the tiles on a roof, and cartilaginous on the margin. They entirely cover the stems, and are persistent for several years, $\frac{3}{4}$ to $1\frac{3}{4}$ in. long, very sharp-pointed, somewhat thickened at the base, but without any footstalk, and remain on the shoots for years quite green, though they get more separated, closely pressed down along the stem, and turned backwards as the tree increases in circumference. Its *branches* are horizontal, somewhat ascending at the extremities, regularly divided laterally, in opposite pairs, and quite straight, from five to seven in a whorl, diminishing in length as they ascend higher up the tree, until at the top they terminate in the leading shoot, and form a kind of pyramidal head. The lateral branches are long, straight, in opposite pairs, and regularly divided; whilst the branchlets are cylindrical, thickly covered all over with leaves, rather slender, undivided, and mostly bent downwards. The male and female *flowers* occur on separate trees. The male catkins are ovate-cylindrical, and in clusters of from six to seven at the ends of the branches; whilst the female flowers are solitary and erect. *Cones* very large, globular, solitary, and standing erect on the ends of the top branches. They are from 6 to 8 in. broad and from 6 to 7 in. long, and are of a dark-brown colour, with the scales regularly and closely imbricated; but when ripe they are deciduous, and very soon fall to pieces (Gordon).

Distribution.—This tree forms large forests in Chili at an elevation of 1600 to 2200 ft., on the Andes, and on the mountains of Caramavida and Naguelbuta, near Conception. It was introduced into Britain in 1796.

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[1] Masters, *List of Conifers and Taxads* in *Jour. Royal Hort. Socy.*, vol. xiv., 1892, p. 197. Throughout this chapter the generic descriptions are mostly those adopted by Masters, and published in the *Report of the Conifer Conference of* 1891; but as no specific descriptions are given in that list, these have been taken partly from Loudon and partly from Gordon's *Pinetum*, 1858.

Description.—The Araucaria often has a height of 150 ft. in Chili, and female trees are said to attain over 200 ft. It grows well in Britain, often making an average annual growth of over 18 in. in height and over 1 in. in girth (at 5 ft. up). A specimen at Dropmore (Berkshire) grew in sixty-four years to 70 ft. high and over 8 ft. in girth. The stem is straight, and covered with hard, sharp-pointed leaves, while the branches droop at first, and again ascend, giving the whole tree a formal appearance, rather suggestive of the arms of a candelabrum. It is quite hardy in most parts of Britain, even in the north of Scotland, if planted on suitable soil; and Continental experience shows that it can grow in the open wherever the temperature does not sink below −15° C. (or 5° Fahr.) during the winter.

Economic Value.—The wood of the Araucaria is rather hard, and might be useful; but the tree can never be of more than arboricultural interest here.

Soil and Situation.—It thrives best on a light soil, which its roots can penetrate easily, and in a free, airy situation. It is unsuitable for low, damp localities, where, like many of our other ornamental trees, it soon becomes sickly; nor does it stand exposure to high winds, which break its branches.

Cultivation.—The Chili Pine is raised from imported seed, which germinates very freely and readily. The seed is about 1 in. long, and is edible; it has an almond flavour. It is generally sown in cold frames, and transplanted into the nursery when one year old; but seedlings need protection during the first winter. In the nursery they require frequent transplanting to encourage the growth of fibrous roots and ensure their establishing themselves when planted out.

(2) THE NORFOLK ISLAND PINE, *Araucaria excelsa* R. Br.

This differs from the Chili Pine in having bright-green, slightly curved, blunt-pointed, compressed, and indistinctly four-cornered *leaves* nearly ½ an inch in length, but broadening at the base, and covering the twigs thickly. The *branches* stand in regular whorls of five or six; the twigs are ranged in double comb-like rows along the branches. The *cones* are situated terminally on long stalks; they are almost spherical, but not so large as those of the Chili Pine, being rather over 6 in. in length and rather under that in breadth. Whereas in the Chili Pine the *seed* is large, unwinged, and edible, in the Norfolk Island Pine it is large, broadly winged, of a blackish-brown colour, and not edible.

On Norfolk Island it grows to over 200 ft. in height. In Central Europe it is not so hardy as the Chili Pine against winter cold, as it can only be grown where the temperature does not sink below −10° C. (or 14° Fahr.)

II. *ABIETINEÆ* Rich.

For British Forestry this is by far the most important tribe of the Coniferæ. It includes seven indigenous and acclimatised genera, which are thus divided (Willkomm):[1]—

[1] In accordance with Bentham and Hooker's *Genera Plantarum*, Masters' *List of Conifers and Taxads*, formally approved at the *Conifer Conference*, 1891, and the *Index Kewensis*, 1893, vol. i. pp. 2 and 3, the correct botanical names for *Spruces* and *Silver Firs* are here adopted in place of Loudon's nomenclature generally used by nurserymen.

The common names of the Conifers are also, however, subject to just as much confusion as exists with regard to the scientific names of the different genera *Picea*, *Abies*, *Tsuga*, and *Pseudotsuga*.

Pinus sylvestris was the only tree of the *Abietineæ* indigenous to Britain, and its name was **Fir**. Of that there can be no doubt; for it is directly traceable from the old Anglo-

A. Cone-scales narrow, and more or less thickened towards the apex; seed only ripens during the second year after flowering; resin-ducts varying in number and disposition. Evergreen trees and shrubs, whose leaves, ranged spirally round the short shoots, are usually from the second year onwards divided into 2, 3, or 5 needles, contained within a membranous sheath. **Pine** . . . . . . 1. *Pinus* L.

B. Cone-scales thin, broad, and becoming thinner at the edges.

a. Leaves single, ranged spirally around the twigs, and persistent for several years. Seeds ripen in one year. Evergreen trees.

α. Older (defoliated) twigs rough, owing to the prominence of the adherent bases of the leaves on the leaf-scars; bracts of the female flower-spike smaller and shorter than the seed-scales; cones mostly pendulous, and with the scales persistent on the spindle or rachis.

(*a*) Leaves sessile, 2- or 4-sided, ranged along the upper and under sides, and with two lateral resin-ducts. **Spruce** 2. *Picea* Lk.

(*b*) Leaves petiolated, 2-sided, with a single resin-duct running along the back of the leaf. **Hemlock** . . . 3. *Tsuga* Endl.

β. Twigs smooth, leaf-scars not prominent; bracts of the female flowering-spike considerably longer than the seed-scale.

(*a*) Leaves petiolated, 2-sided, with two lateral resin-ducts below the under surface; leaf-scars transversely oval; cones pendulous when ripe, with the scales persistent to the spindle or rachis. **Douglas Fir** . . . . 4. *Pseudotsuga* Carr.

(*b*) Leaves sessile, 2-sided, with two lateral resin-ducts near the edges; leaf-scar circular; cones erect, but with deciduous scales which fall away from the spindle on the ripening of the seed. **Silver Fir** . . . . 5. *Abies* DC.

b. Leaves of the short shoots clustered in tufts, but occurring singly on the long shoots that develop later on.

α. Deciduous trees, whose cones ripen within one year from the flowering. **Larch** . . . . 6. *Larix* Lk.

β. Evergreen trees, whose cones only ripen during the second year after flowering. **Cedar** . . . . 7. *Cedrus* Lk.

1. THE PINE, *Pinus* L. (Linnæan System, Monœcia Monadelphia).

Generic Character.—True Pines are evergreen trees, with the adult *leaves* persistent, in tufts of 2, 3, or 5 needles; the *flowers* are monœcious, males in catkins; pollen cells winged; *cones* ripening in the second year, woody; *scales* (relatively) thin at the tips in *P. Strobus* and *P. Cembra*, thick in *P. Pinaster*. Wing of the *seed* ultimately separable, dilated above, prolonged below into two claw-like processes which clip the wings of the seed. *Cotyledons* variable in number, 3-sided, usually entire, whilst the primordial leaves are denticulate (Masters).

Saxon *Fuhr*, which still survives as *Fuhre* or *Föhr*, the common modern name of this tree throughout Northern Germany (although the term *Kiefer* or Pine is even commoner in the north, and is general throughout Southern Germany). Its Gaelic name was *Guithes*, which still survives in place-names (*e.g.*, Kingussie).

If, however, the different genera of the *Abietineæ* are all called **Firs**, this unscientific and unpractical nomenclature must produce immense confusion. It is indeed absurd to call *Pinus Laricio* the Corsican Fir, *Picea excelsa* the Spruce Fir, and *Pseudotsuga Douglasii*, *Picea grandis*, and *Araucaria excelsa* respectively the Oregon, the Vancouver Island, and the Norfolk Island Pines. The best practical solution of the difficulty seems to be that every species of the genus *Pinus* should always be called **Pine**; *Picea* (Link.), **Spruce**; *Tsuga*, **Hemlock**; *Pseudotsuga*, **Douglas Fir**; *Abies* (DC.), **Silver Fir**; *Larix*, **Larch**; *Cedrus*, **Cedar**.

The Pines are all evergreen trees, mostly of large size, indigenous to the hilly regions of Europe, America, and Asia. They are perhaps the most useful of all trees to mankind. Nearly all the species in Britain flower in May and June, and they generally ripen their cones within two years of flowering. They all thrive best on a light, dry, porous soil; and pure air, such as is found on elevated sites and at a considerable distance from the smoke of towns, is necessary for their healthy growth. They are all unfavourably influenced in growth by wetness of soil, and they do not succeed on heavy, retentive land. They are really better suited for a poor than a rich soil; and most of the species introduced from America and Asia do better on south-west and north aspects than on easterly or southern exposures.

They grow gregariously; and as they are at the same time *light-demanding* rather than *shade-bearing* trees, Pine-woods are consequently thin as compared with forests of Spruces and Silver Firs. Even when growing in isolated positions, they throw off most of their lower branches, and form straight, clean boles, the bark of which becomes thicker and much fissured with age. The leaves or needles are persistent only from three to six years, although on inferior classes of soil they are shed sooner, defoliation usually taking place in autumn. As they approach maturity the shoots of the branches forming the crown grow more vigorously than the leading-shoots; and the crown consequently becomes rounded off, in place of remaining more or less conical like that of Spruces and Silver Firs. Most Pines have a well-developed tap-root, and a deep, widespreading root-system, which enables them to offer considerable resistance to storms. The timber of most Pines is usually rich in resin; and like all trees which have a decided tap-root, they form a heartwood of a much deeper colour than the alburnum or sapwood.

According to Willkomm, there are at least 83 species of Pines, with more than 170 varieties. The only kinds that have any sort of interest for Britain may perhaps be most conveniently considered according to the number of needles enclosed within each sheath and forming the complete leaf, as follows:—

I. *Leaf geminate, or consisting of Two Needles in each Sheath*—

(1) Pinus sylvestris.	(7) Pinus pyrenaica.	(12) Pinus muricata.
(2) " austriaca.	(8) " Brutia.	(13) " persica.
(3) " Laricio.	(9) " Mughus.	(14) " pinea.
(4) " Pinaster.	(10) " Pumilio.	(15) " halepensis.
(5) " Pallasiana.	(11) " inops.	(16) " Banksiana.
(6) " resinosa.		

II. *Leaf ternate, or consisting usually of Three (but exceptionally of Two or Four) Needles in each Sheath*[1]—

(1) Pinus Gerardiana.	(5) Pinus Benthamiana.	(9) Pinus Sabiniana.
(2) " macrocarpa.	(6) " rigida.	(10) " Jeffreyii.
(3) " Bungeana.	(7) " radiata.	(11) " tuberculata.
(4) " ponderosa.	(8) " insignis.	

III. *Leaf quinate, or consisting usually of Five Needles in each Sheath*—

(1) Pinus Strobus	(4) Pinus Lambertiana.	(6) Pinus monticola.
(2) " Cembra.	(5) " Montezumæ.	(7) " Hartwegii.
(3) " excelsa.		

[1] The three-needled (*ternate*) species of Pines have, like Larches and some kinds of Silver Firs, a slight power of shooting from the stool and rooting from slips. But this is merely a physiological curiosity, and not of any practical utility.

The only 2-needled (geminate) Pines of importance as regards British Forestry are (1) Scots, (2) Austrian, (3) Corsican, and (4) Maritime Pines, which are distinguishable as follows :—

Species of Pine.	Buds.	Needles (in each of these four species the entire leaf is divided into two needles).	Cones.	Seeds.	Cotyledons.
(1) Scots Pine (*P. sylvestris*)	Ovate, bluntly pointed ; 4-6 side - buds, usually clustered around central bud of leading-shoots	$1\frac{1}{2}$ - $2\frac{1}{2}$ in. long ; light blue-green or grey ; finely serrated along edges ; persistent for 2 to 3 years (according to quality of soil)	Generally in pairs ; 2-3 in. by 1-$1\frac{1}{4}$ in. ; irregular 4-sided ; point often recurved ; reddish-brown when ripe	With wing, 1-$1\frac{1}{4}$ in. long	5 to 7
(2) Austrian Pine (*P. Austriaca*)	Large ; leader often 1-$1\frac{1}{4}$ in. long ; ovate, with a long point	2-5 in. long ; seldom twisted, and then only slightly ; stiff, strong, and prickly ; sheath with 3-5 rings, darkening with age	2-3 in. long ; conical ; rounded at base ; pointing nearly horizontally ; light-brown, polished and shining	A good deal larger than those of the Scots Pine	6 to 8
(3) Corsican Pine (*P. Laricio*)	Resinous ; ovate ; with long narrow point	4-6 in. long ; dark-green ; often twisted, and rather slender ; with shorter sheaths than Austrian Pine ; persistent for 3 to 4 years	Solitary, or in pairs ; seldom over 3-4 in. long, and $1\frac{1}{2}$ in. broad at base ; conical ; straight, or only slightly pointed at apex	About twice as large as those of the Scots Pine	6 to 8
(4) Maritime Pine (*P. Pinaster*)	$\frac{3}{4}$ in. long ; white, woolly, imbricated and non-resinous ; with scales turned back at the points	6-8 in. long ; dark-green ; rigid, broad, and very stout ; thickly set in dense whorls ; sheaths $\frac{3}{4}$ in. long, imbricated, pale-yellow, then turning nearly black	4-6 in. long, and $2\frac{1}{2}$ wide at broadest part ; light-brown and shining ; in clusters of 4-8, and sometimes more ; pointing horizontally ; without footstalks	Oblong ; with wings $1\frac{1}{2}$ in. long and nearly $\frac{1}{2}$ in. broad	7 or 8

I. GEMINATE PINES, HAVING TWO NEEDLES IN EACH LEAF-SHEATH.

(1) THE SCOTS PINE or COMMON FIR, *Pinus sylvestris* L.

SYNONYM—*P. rubra* Mill.

Specific Character.—*Leaves* divided into 2 needles, rigid, from $1\frac{1}{2}$ to $2\frac{1}{2}$ in. in length, somewhat waved and twisted ; slightly concave on the upper and convex on the under surface, of a light bluish-green or greyish colour ; finely serrulated on the edges. *Sheaths* jagged and slightly ringed. *Cones* from 2 to 3 in. long, and from 1 to $1\frac{1}{4}$ in. broad, terminating in an irregular 4-sided, projecting point, often recurved. *Seeds*, with the wing, from 1 to $1\frac{1}{4}$ in. long ; cotyledons from 5 to 7 in number (Gordon).

Distribution.—This is the only species of the Pine genus indigenous to Britain. In favourable situations it is one of our largest and hardiest forest-trees, growing in Scotland up to 2000 ft. above the sea-level. At one time it formed vast pure forests throughout the Scottish Highlands and in parts of the Lowlands. Remains of these ancient woodlands are still to be found around Invercauld, Rothiemurchus, Glenmore, Abernethy, and Duthal, where may be seen some of the finest Scots Pine in Britain. Fossil remains show that it was at one time indigenous to the south of England, where it died out and was reintroduced, in 1776, into Hampshire.

The first plantation made then was in Ocknell Clump, an old "encoppicement" replanted in 1776, though probably the Pines in Boldrewood also date from about the same time. The planting of Firs (Pines) and Larch was strongly recommended by the Commission of 1787-93, but no such use of the Scots Pine was made on a large scale until after the passing of George III.'s *Act for the Increase and Preservation of Timber in the Dean and New Forests*, in 1808, when commissions were issued in 1809, 1814, and 1819 for extensive planting, amounting in all to some 5250 acres. . . . Since then the Scots Pine, one of the kinds of trees best suited for poor, sandy soil, has been introduced so largely into Hants and other southern counties as to be one of the most characteristic features of all sandy and moorland tracts, spreading itself naturally wherever it gets any fair chance of doing so. (Article on *Forestry and the New Forest* in *Victoria County History of Hampshire*, vol. ii., 1903.)

It is indigenous throughout most of Northern Europe and Asia, but has not yet been found of spontaneous growth in America. It is the chief tree throughout Northern Germany, and the Baltic provinces of Russia, Sweden, and Norway; and it forms the chief and the best wood imported from the Baltic under the trade names of "red pine," "red fir," "red deal," and "yellow deal," according to its place of production and shipment,—as distinguished from the "white fir" or "white deal" of the Spruce, the "Swiss pine" or "white pine" of the Silver Fir, the "yellow pine" or "white pine" of the Weymouth Pine, and the "pitch pine" of *Pinus palustris*, the long-leaved Pine of the Southern States of America.[1]

Although it has not so large a European distribution as the Spruce, the Scots Pine has a more extensive general distribution; for it is to be found throughout the greater part of Europe, and also over a large portion of Northern Asia. The area over which it occurs stretches from Western Spain eastwards to the drainage of the Amur, and from Lapland and Arctic Russia southwards to Upper Italy in Europe and Asia Minor and Persia in Asia. Both its polar and its equatorial limits form broken lines owing to climatic causes; but the total area of its distribution may be assessed at about 123° of longitude and 30° of latitude, or rather more than one-third of the northern hemisphere. From the climatic conditions obtaining in portions of this great area, it is therefore evident that it can thrive normally with a lower average annual temperature than the Larch; and the essential conditions for its growth are thus summarised by Willkomm:—

The essential conditions for the thriving of the Scots Pine are a period of winter rest for at least three months, with at least an equal period of active vegetation annually, during which the sky is not continuously obscured or darkened by misty clouds; a sunny situation, such as the southern slopes of mountain-ranges; protection against accumulations of snow and ice; and light, porous, sandy-loamy soil, with a continuously moist subsoil, or else a generally dry or fresh soil.

Description.—In the natural forests yet remaining in Scotland, Scots Pine sometimes has a height of about 80 ft., and a diameter of about 4 ft.,

[1] Interesting details will be found in an article on *Our Imported Coniferous Timbers*, in the *Trans. Roy. Scot. Arbor. Socy.*, vol. xvii., part ii., 1904, pp. 238-242.

whilst many of the trees are between 300 and 400 years of age. Some of the finest Pine-woods are those near Gordon Castle, Castle Grant, and Invercauld. But in many other parts of the country trees are to be found ranging from 70 to 115 ft. in height, and from 3 to over 5 ft. in diameter. In the close canopy of Continental forests the Scots Pine can attain a height of 100 to 120 ft. at from 70 to 120 years of age.

According to the *Report of the Conifer Conference* in 1891, p. 570, the largest Scots Pine then reported on in Britain was at Studley Royal in Yorkshire: it had a height of 90 ft., and a girth of 11¼ ft. at 5 ft. from the ground. Two of the largest I saw in S.E. Ireland (1903) were on the Mount Usher estate (Ashford, Co. Wicklow): one girthed 11 ft. 6 in. at 5 ft. up, and the other 11 ft. 9½ in. at 3 ft. up.

Few trees are so picturesque as old Scots Pines. The stem is comparatively smooth, though not like that of Spruces and Silver Firs, and is generally straight and clear of branches for a considerable way up. If in healthy growth, the bark is usually deeply furrowed, of a reddish colour on the upper portion of the bole, and the cortex scales off freely on the reddened upper portion. This reddening of the Pines is usually a sign of a favourable locality.

In some parts of the south of Ireland old Pine-trees take a peculiar habit of growth, the crown being broad and fairly compact, and the bark broad-flaked and deeper fissured than usual. It is claimed that this is a separate variety, and it is locally known as the Irish Pine. The finest specimens of this kind of tree that I have seen are on the Doneraile estate, in Co. Cork.

Economic Value.[1]—The quality of Scots Pine timber is much influenced by the nature of the soil and situation upon which it is grown, as well as by the age at which the tree is cut. But, with the exception of the Larch (the best of all) and the Douglas Fir (ranking about half-way between Larch and Scots Pine), it is on the whole the best wood yielded by any Conifer in Britain. The mature, close-grained, highly resinous timber produced upon cold high-lying districts in the north of Scotland is superior to wood imported from Continental Europe; while that grown in the Lowlands and in most parts of England is nothing like so red-hearted and durable. Scots Pinewood is used for almost all kinds of purposes. When from 6 to 8 in. in diameter, thinnings from plantations can be used for making staves for barrels of dry goods, and for many similar purposes. Fully matured timber of large dimensions is used very largely for boards and scantlings, and beams, &c., for building purposes. Large quantities are also used for railway sleepers and pit-props. Its mean sp. gr. is 0·82 when green and 0·52 when seasoned, so that it may easily be floated immediately after being felled.

It is not so elastic as Larch or Spruce, but more so than Silver Fir; but it shrinks to about 3 to 5 per cent of its volume when green, whilst these other woods only shrink from about 2 to 3 per cent. In general durability it ranks below Oak, Larch, and Douglas Fir.

Soil and Situation.—With regard to the quality of the soil upon which

[1] Such data as are available concerning the yield of timber per acre of Scots Pine, Spruce, Silver Fir, and Larch, will be found in vol. ii. Part II. (*Management of Woodlands*).

it may be grown, the Scots Pine is one of the most accommodating of our forest-trees. It is often found on peaty soil in the north of Scotland, and has been planted chiefly on sandy soil throughout the south of England. The best qualities of Scots Pine timber are, however, produced in Scotland on a gravelly loam, resting upon a dry stratum of rotten rock; but excellent timber may also be formed upon a dry sandy loam. On a thin light surface-soil, resting on a subsoil of gravelly till, it also often grows into good timber. The Pine forests of Strathspey are generally on a sandy gravel; and timber is there produced of large size and the best quality.

The investigations and analyses made by Continental scientists have proved (see Part III., *Sylviculture*, chap. i.) that Scots Pine makes only moderate demands on the soil, both as to mineral food and as to the amount of water withdrawn for transpiration. In this latter respect it ranks above Spruce and Silver Fir—which seems contrary to experience, until it is considered that by means of its deep tap-root it can imbibe large quantities of moisture from the subsoil underlying land that may appear dry on the surface. On a binding soil it neither grows so well, nor produces such good timber, as on lighter soil of any description. But, of course, the length and persistence of the foliage, the height and straightness of the bole, the density of the crown, and the capacity for maintaining close canopy in woodlands, all depend on the general quality of the soil with regard to depth and freshness, and of the situation with regard to freedom from exposure to exhausting winds.

Cultivation.—The Scots Pine is grown entirely from seed. It cannot spring from the stool, or send up root-suckers; and that is the reason why the ancient forests, killed by fire, were destroyed completely. The cones ripen in the second autumn after the flowering, and the seed is shed during the ensuing spring. For nursery requirements, the cones should be gathered during the winter, and preferably in December and January, as the scales afterwards open more readily with heat than when they are harvested in November.

A piece of good light ground should be chosen as the nursery, and well prepared by digging and by repeated raking. Then it should be marked off into parallel beds of 4 ft. in breadth, with a 1 ft. path between them. The seed should be sown at an average of about two seeds to the square inch, and covered with about a quarter of an inch of fine soil. When one year old, the seedlings should be transplanted into the nursery-rows for one or two years. In forming plantations at high elevations, Scots Pine may be planted either as yearling seedlings or as two-year-old transplants that have stood for one year in the nursery-lines. But if plants of about 9 in. are wanted, then in that case the transplants should stand for two years in the nursery-rows.

Existing forests of Scots Pine may easily be regenerated naturally by leaving rows of seed-bearing trees very wide apart on the better classes of soil; but on inferior land planting has usually to be adopted. The formation of new woods may take place either by sowing or planting; but on the whole planting is much preferable, as the growth of grass and herbage is usually so rank that the seedlings are smothered.

Sylvicultural Characteristics.—The relation of the Scots Pine towards light and shade furnishes the key to all the special characteristics peculiar to its growth as a forest-tree. Even though in our damp insular climate it forms a better crown of foliage and maintains itself longer in close canopy than on the sandy soil and in the dry climate of the great North German plain (where it is the chief tree), yet it must be classed as a *light-demanding* tree when compared with the more densely foliaged Conifers like Common and Menzies Spruce, Hemlock, Douglas Fir, Silver Fir, Nordmann's Fir, or even Weymouth Pine and the Black Pines (Austrian and Corsican).[1]

The growth of Scots Pine is usually neither so straight as that of the Spruces or Silver Firs (for its leading-shoot is apt to be damaged by numerous insects and by fungous diseases), nor so free of branches and so full-wooded. Although the branches formed by the Scots Pine are somewhat thicker than those of the Spruce, yet they die and are thrown off sooner, owing to the inherent light-demanding nature of the tree. But, of course, this demand for light is not so urgent on good fresh land and on sheltered situations as under less favourable conditions. Yet Pine would never do for underplanting, which is a special quality of the *shade-enduring* species having denser foliage. On the better classes of land Scots Pine will thrive well when intermixed with other trees of slightly slower growth, so that it can keep its crown fairly free ; and in such mixed crops it is less exposed to attacks from insects or fungous diseases, and forms a better bole and a larger proportion of heartwood, than when grown in pure crops. But on inferior land, not good enough to grow other kinds of forest-trees at a profit, it is often best to plant Pines along with a few Larch.

Continental Notes.—Good naked one-year-old seedlings or two-year-old transplants are preferred to older transplants with balls of earth around them ; for the plants can be moved without much danger of the tap-root being injured. On light sandy soil, when planting can take place easily with

[1] The evergreen Conifers (including the pseudodrupaceous Yew for convenience) retain their foliage on the average as under :—

Species of Conifer.	On inferior soil and situation.	On good soil and situation.	Sylvicultural character.
	Years.	Years.	
Scots and Weymouth Pines	2	3	Light-demanding (Scots) ; can endure a fair amount of side-shade (Weymouth).
Austrian, Corsican, and Maritime Pines	3	4	Not altogether impatient of side-shade.
Cembran and Mugho Pines	4	5	
Douglas Fir, Spruce, Balsam Fir, Menzies and White Spruces	5	7	Can tolerate a considerable amount of shade (varying according to the quality of the soil).
Silver Fir and Black Spruce	6	9	
Yew	7	12	
Spanish Silver Fir	10	15	

wedge-like notching spades, the plantations can be formed at a very low cost per acre. Throughout the German forests there are always temporary nurseries made near where planting operations are likely to be carried out in the immediate future, so that the plants may be ready at hand whenever required, without any special cost being incurred for material or carriage. This also obviates the risk of the transplants drying or sickening before reaching the area to be planted up. As a rule, the planting operations are carried out in spring; and with small plants, like yearling seedlings and two-year-old transplants, close planting at about 3½ ft. by 3½ ft., or else in rows giving about the same growing-space per individual plant, is favoured. Pine soon shoots up, and in upward growth it is only excelled by the Larch among European Conifers. The young plants do not begin to form regular whorls until their third year.

Whenever cones can be conveniently collected, it is advisable to harvest the seed for home use, or at any rate to obtain it only from trustworthy seedsmen, and under guarantee that it is not imported from Germany; for experience has shown that young seedlings and transplants raised from foreign seed are much less hardy as regards late frosts and drought, and that they are also more liable to attacks from the "*leaf-shedding*" disease caused principally by the fungus *Lophodermium pinastri*, although it may also result from drought and frost.

(2) THE BLACK or AUSTRIAN PINE,[1] *Pinus austriaca* Höss.

SYNONYMS—*Pinus Laricio austriaca* Endl.; *Pinus nigricans* Lk. and Host.; *P. pinaster* Bess.; *P. Laricio* Pokorny., Heuff., and Schur.; *P. maritima* Ait. and Koch.

Specific Character.—*Sheath* with from 3 to 5 rings, at first of a clear ash-grey, then becoming reddish, afterwards darker, and at last black. *Leaves* divided into 2 needles, from 2 to 5 in. long, seldom and but slightly twisted; when young, erect; when older, standing out, and curved towards the twig; outer surface half-round, dark-green, glossy, and with a sharply serrated margin; inner surface nearly even, but slightly dotted along the ridge; points prickly, of a yellowish-brown or fawn colour. *Buds* large, the leader often from 1 to 1¼ in. long, ovate, with a long point. The *cone* does not arrive at maturity till October in its second year; it is conical, rounded at the base, 2 to 3 in. long, pointing horizontally, or nearly so; of a light-brown colour, polished, and shining. *Seeds* very closely resembling those of the Corsican Pine (*P. Laricio*); and the cotyledons from 6 to 8 in number, as in that species. The bark of the shoots of the current year is of a greenish-yellow, regularly and deeply raised by the insertions of the leaves, furrowed, and shining (Loudon).

Distribution.—The Black Pine grows indigenously in Austria, in the Breima Forest (Wienerwald), the Banat, upon the Demoglet, near Mehadia, and in the

[1] The **Austrian Pine**, the **Corsican Pine**, and the **Taurian Pine** are by Continental botanists considered mere climatic varieties of one species—the **Black Pine** (*Pinus Laricio* Poir.) But as they have long been treated by British arboriculturists as separate species, no attempt is here made to group them together. A monograph on the Black Pines (Austrian and Corsican) is to be found in the *Transactions of the Highland and Agricultural Society of Scotland* for 1876, fourth series, vol. viii. p. 220. See also *Trans. Scot. Arbor. Socy.*, 1875, pp. 52-59.

neighbourhood of the Snowy Mountains, at higher altitudes than the Common Silver Fir. It is a characteristic tree of the Austrian flora, where it forms large natural forests throughout lower Austria, Carinthia, Hungary, Croatia, Dalmatia, Bosnia, the Herzegovina, and along the coast. Its climatic requirements are a hot summer, a mean annual temperature of not less than 45½° Fahr., and a winter that is not excessively cold (Willkomm). It was introduced into Britain in 1835.

Description.—The Austrian Pine differs from other Pines by its robust habit of growth, the stiffness, strength, and prickly points of its leaves, and the dark appearance of its foliage. It is as hardy as Scots Pine, and can do well in woods above 1000 ft. in elevation, often outgrowing Larch and Scots Pine mixed with it. It is at the same time a distinctly ornamental tree, with full rich foliage.

On favourable soil and situations it grows to a height of 70 to 100 ft., with a stem of 10 to 12 ft. in girth; but on poor, dry, limy land it is often little better than a large shrub of upright pyramidal shape. In Austria it is often to be found of large dimensions, and sometimes attains over 500 years of age. One of the celebrated giant Pines in the Wienerwald, near Vienna, is over 20 ft. in girth at breast-height (Willkomm).

Economic Value.—Although highly valued for general purposes in Austria, where it is of equal importance to what the Scots Pine is in Britain, yet the coarseness of the wood grown in our climate is against the cultivation of Austrian Pine on any very large scale here,—though it will always be of especial value in the replantation of poor limestone tracts. Its wood is somewhat heavier than that of the Silver Fir, the mean sp. gr. being 0·97 when green and 0·51 when seasoned.

In general durability it ranks close to the Scots Pine on the Continent, but the timber produced in Britain is much coarser in the fibre, less resinous, and not so durable. Even though it gives a larger yield of timber per acre than Scots Pine, yet, bulk for bulk, the latter brings the better price, so that on the whole Scots will in most cases prove the more profitable crop to grow. It is somewhat harder than Scots Pine, but not so elastic. Like the latter, it has a greater shrinkage (3 to 5 per cent) than Weymouth Pine, Spruce, Silver Fir, Larch, or Arborvitæ (*Thuja*), whose loss in bulk is usually only from 2 to 3 per cent of the volume when green. The timber of the Austrian Pine is better adapted for pit-work and use in the ground than for general building and carpentry purposes. No other resin (not even that of the Maritime Pine) is so rich in oil of turpentine as that of the Austrian Pine; for 100 lb. of it yields from 14 to 20 lb. of oil of turpentine, and about 60 lb. of colophonium or rosin (Gayer, *Forstbenutzung*, 1888, p. 501).

Soil and Situation.—So long as the soil is neither stiff nor wet, the Austrian Pine is decidedly accommodating. It even grows well on dry sloping banks of deep, light loamy soil, and plantations will thrive on most kinds of wet land after these have been drained. It is useful for providing shelter to less hardy species planted along with it; for its thick foliage and rapid growth afford protection soon after planting. It grows well near the sea-shore, and is nearly as hardy as the Cluster or Maritime Pine.

Continental experience shows that it grows best in a warm, dry climate, and that, although its finest development is attained on a limy soil, it is one of the most accommodating of trees. According to Ebermayer's analyses it withdraws less mineral food from the soil than any of the other coniferous timber-trees; but, though able to thrive on what may seem a dry sandy soil at the surface, it withdraws more water for transpiration through its foliage than any of the other Conifers commonly grown in woodlands.

Cultivation.—The seeds being a good deal larger than those of the Scots Pine, they should be much more thinly sown than the latter, and covered a little more deeply with soil. Otherwise the treatment is the same as for Scots Pine.

Sylvicultural Characteristics.—The chief use of the Austrian Pine consists in its great accommodative power on poor limy or sandy soil, and in its being less impatient of shade than the Scots Pine, although it cannot be classed among *shade-enduring* trees like Spruce, Silver Fir, and Douglas Fir. Its long thick needles form good humus, and soon improve land that has become deteriorated by the exhausting action of sun, wind, and rain. Though it has a better crown of foliage than Scots Pine, the Black Pine cannot be said to maintain very much better canopy overhead, or to be content with a much less individual growing-space, because it soon shows a strong tendency to spread into branches.

Except in being a little more tolerant of side-shade, its sylvicultural characteristics closely resemble those of the Scots Pine. It is equally hardy as regards frost; but even on sandy soil it sometimes endures long-continued drought better than the latter. Indeed, in this respect, as also with regard to transplanting, the Austrian Pine is far more hardy than Corsican Pine. On good classes of soil Black Pine may easily be regenerated naturally by leaving about 25 or 30 stems per acre as seed-bearers; but clear-felling and replanting are the usual method.

Continental Notes.—For light classes of soil in which notching or other simple methods of planting can take place, a preference is usually given to naked yearling seedlings or two-year-old transplants; and when older plants are required, they are pitted with balls of earth around the roots. When transplanted into the nursery-rows the yearling seedlings are usually put out at 6 in. from plant to plant, in rows about 10 to 12 in. apart; and in the course of a couple of years they develop into sturdy plants.

Black Pine woods are prolific in producing good seed between the ages of thirty and sixty years. The cones should be collected in March or early in April, before the seed begins to be scattered during warm days.

In the Austrian State forests the seed is harvested by exposure of the cones to the sun's warmth; but kilns are also in use for the supply of seed to seedsmen. According to Burckhardt, these kilns are worked by means of air-chambers, warmed from below, and heated to a temperature of 104° to 111° Fahr., having funnels or vents in the ceiling for permitting the escape of the vapour and gases given off from the heated cones. When the operation has been carefully conducted, 75 per cent of the seed should sprout; for in germinative power Black Pine seed is only second to that of Spruce (75 to 80 per cent).

(3) THE CORSICAN PINE, *Pinus Laricio* Poir.

SYNONYMS—*Pinus Laricio Poiretiana* Endl.; *P. L. calabrica* Delam.; *P. corsicana* Poir.; *P. sylvestris maritima* Ait.

Specific Character.—*Leaves* divided into 2 needles in a sheath, from 4 to 6 in. long, dark-green, often twisted, and rather slender for its class, and with shorter sheaths. *Cones* solitary, or in pairs; seldom more than 3 or 4 in. long, and 1½ in. broad near the base, conical, straight, or sometimes slightly curved near the points. *Buds* ovate, with a long narrow point, and resinous. *Seed-leaves* from 6 to 8 in number (Gordon).

Distribution.—The Corsican Pine, a species of Black Pine, was first discovered in Corsica, hence its name. It forms large forests on the Sila mountains in Calabria, and has been found throughout most of Southern Europe, in Greece, Crete, Italy, Sicily, Corsica, and Spain, as well as on the Caucasian mountains in Russia. It was introduced into Britain in 1759. It attains its finest development in Corsica, where stems of from 10 to 20 ft. in girth are still not uncommon. Stems of 1000 years of age are not rare in Southern Europe, and von Seckendorff estimated that some of the gigantic stems in the Valley of Trottalia are from 1500 to 1800 years of age (Willkomm).

Description.—It grows rapidly, and reaches a height of 90 to 120, and sometimes even 150 ft., with a proportionate girth of stem. It is hardy and accommodating, and is found on Mount Etna at elevations between 4000 and 6000 ft. Even in this country it is hardy except as regards drought.

It is easily recognisable from other species by its branches being in very regular whorls, and spreading out in an open, horizontal manner, giving the whole tree a peculiarly free and open character. It may further be easily known by its leaves being wavy and set loosely on the branches, and by their having shorter sheaths than the Austrian or the Taurian Pine, by their being thinly dispersed over the shoots, and by the terminal buds of its shoots being comparatively long and tapering to a point. It flowers in May, and its cones ripen in the November of the second year. It often makes shoots of 2 to 3 ft. in height and seldom less than 2 ft., after once its root-system has established itself. It is a general favourite with tree-growers owing to its full rich foliage, its deep root-system, and its great longevity.

The two largest stems recorded by the Conifer Conference in 1891 were 79 ft. high and 5¾ ft. in girth (at 5 ft. above the ground), and 69¼ ft. high and 7 ft. 7½ in. in girth. In 1903 the former girthed 8 ft. (52 years old), and the largest known specimen (74 years) was 102 ft. high and 10 ft. 3 in., growing in Bucks (Somerville).[1]

Economic Value.—The timber is coarse in grain and whitish in colour, but brownish in the heartwood, and highly impregnated with resin. Though coarse-fibred it is elastic, is fairly easy to work, and is durable owing to its resinousness. It produces a larger quantity of wood per stem and per acre than Scots Pine, but as its price per cubic foot is less, it does not necessarily follow that it is a more profitable tree to grow as a timber-crop.

Soil and Situation.—Like all other Pines, the Corsican Pine grows most

[1] Article on *Exotic Conifers in Britain*, in *Journal of Board of Agriculture*, Dec. 1903, pp. 319-346.

rapidly on a light, dry, sandy loam, with a well-drained subsoil; and heavy, cold, moist clays do not suit it. And, of course, the more sheltered the situation, the better it is for the trees. They do not thrive on high-lying situations in this country; for their roots are not so well adapted as those of Scots Pine for offering resistance to high winds acting with the leverage of a heavily-foliaged top. Except as regards drought it is as hardy as Scots or Austrian Pine; and it is less bitten by rabbits, squirrels, and voles.

Cultivation.—The seeds, which are about twice as large as those of the Scots Pine, should be sown thinly, about one to the square inch, on the seed-beds; and they should be covered with about three-eighths of an inch of earth. Unfortunately, owing to a weak root-system, it does not well bear transplanting. From the difficulty it thus finds in establishing itself, large numbers die off in plantations—more especially during warm, dry summers, when one-half to two-thirds, or more, of the young plants sometimes succumb.

Its **Sylvicultural Characteristics** are similar to those of the Austrian Pine.

(4) THE TAURIAN PINE, *Pinus Pallasiana* Lamb.

SYNONYMS—*Pinus Laricio Pallasiana* Endl.; *P. maritima* Pall.; *P. caramanica* Oliv.; *P. taurica et tatarica* Hort.

Specific Character.—*Leaves* divided into 2 needles, very long, sharp-pointed, erect, rigid, 5 to 6 in. long, and channeled above; smooth, crowded, and of a shining dark-green. *Sheaths* short, ½ in. long, covered with scales, and torn on the margin; white when young, but dark-brown when old. *Buds* ovate, 1¼ in. long, and resinous, with the sides hollow. *Branches* scattered irregularly along the stem, robust, and incurved upwards; some of the lower branches are nearly equal to the stem in size. *Cones* ovate-oblong, tapering to a point, without footstalks, often curved near the end, 4 or 5 in. long, and 1¾ in. broad at the widest part near the base; horizontal or incurved downwards, mostly single, or in threes round the branches, and of an ash-grey colour. *Seeds*, middle-sized, with a broad wing (Gordon).

Distribution.—On the Continent the Taurian Pine is, like the two preceding species, considered a mere climatic variety of the BLACK PINE (*P. Laricio* Poir.), confined chiefly to the central regions of the Crimea and of Asia Minor, where it forms large forests on the western slopes of the chain of lofty mountains extending along the coast of the Black Sea. It was introduced into England about 1790.

Description.—It is generally a large tree of spreading habit, which usually sends out numerous large horizontal branches, and whose lower branches are often nearly as large as the main stem. The bark becomes cracked, rugged, and brown, and then scales off. But in its native tracts it is to be found from the size of a small tree, bearing tiny cones, up to 100 ft. in height, and bearing cones of 4 in. in length. It is easily distinguishable from the other two Black Pines by huge knots formed along the stem, and by the large dimensions that some of the lower branches generally attain. It is hardy, grows rapidly, and is ornamental. In Britain it grows to over 50 ft. high and over 7½ ft. in girth.

Economic Value.—The timber of the Taurian Pine is durable, though knotty and difficult to work. But it is not a tree for extensive planting in our woodlands.

Soil and Situation.—The Taurian Pine is accommodative as to soil. Well-grown trees may be found on poor, thin, gravelly soil and on stiff loam; but it requires a dry and porous subsoil. It grows well on limy soil and chalk land, and thrives near the sea-coast.

Cultivation.—Seedlings are raised in the same way as those of Scots Pine.

(5) THE PINASTER, CLUSTER, or MARITIME PINE,

Pinus Pinaster Soland.

SYNONYMS—*Pinus maritima* Lamk., Poir., DC. ; *P. Pinaster* Loud., Link., Endl., Carr.

Specific Character.—*Leaves* divided into 2 needles, dark-green, 6 to 8 in. long, rigid, broad, and very stout, slightly serrated on the margins, and thickly set on the branches in dense whorls; *sheaths* ¾ in. long, imbricated, and pale-yellow when young, but turning nearly black when old; *buds* ¾ in. long, white, woolly, imbricated, and non-resinous, with the scales turned back at the points. *Cones* from 4 to 6 in. long and 2½ in. wide at the broadest part, which is below the middle, and of a light shining brown colour, and growing in clusters of from 4 to 8, but sometimes more in number, in a horizontal direction, and without any footstalks. *Seeds* oblong, with wings 1½ in. long, and nearly ½ in. broad. *Seed-leaves* from 7 to 8 in number (Gordon).

Distribution.—The Pinaster is indigenous to the south of Europe and both shores of the Mediterranean. It is abundant in Spain. From Greece it extends eastwards into Western Asia. It was introduced into Britain in 1596.

From Portugal to Eastern Greece, and from Dalmatia to Algiers, its natural distribution extends over more than 30° of longitude and 10° of latitude. But it is chiefly to be found on islands or within the influence of a purely seaboard climate, where it frequently forms almost pure woods, as well as mixed with the Black Pines and broad-leaved species of trees. Willkomm considers that the climatic conditions for its growth are a mean annual temperature not below 53½° Fahr., and a mean winter temperature of at least 43° Fahr.

Description.—The Pinaster or Maritime Pine (also called the Cluster Pine from the star-like clusters of cones, which point downwards) is a large and handsome tree, resembling the Black Pines in general appearance. When standing alone, it forms a widespreading tree of massive appearance. The stem is clothed with coarse, deeply-furrowed bark, which gives the tree a rugged look. The branches are in regular whorls, and always turn somewhat upwards. The leaves are generally from 6 to 8 in. long, although sometimes nearly 1 ft. in length. It has a decided tap-root, which goes deep into dry, porous soil; but its side-roots are generally weak, and the tree has a heavy, densely-foliaged crown; it is generally found leaning over somewhat to one side, in place of being quite erect and perpendicular. It is hardy in low-lying situations, but is not suited for highly elevated and exposed parts. Yet no tree of the Pine genus is better adapted for growth along the sea-shore, where it is one of our most useful trees for enduring the blasting influences of sea-breezes. In France immense tracts of barren, drifting sands, known as the *Landes*, and lying to the south of Bordeaux, have been covered with plantations of this tree, which are now of great value both for their timber and for the resin and tar prepared from them, and for the shelter provided for agriculture.[1]

The Maritime Pine is of a very spreading habit at all stages of its growth. When planted along the sea-shore, with plenty of room to develop this branching habit, it forms good protection for more valuable and less hardy trees; but if the trees forming such outer belt be confined in growing-space, they show their natural tendency as a *light-demanding* species, and soon lose their branches and assume a drawn-up, weakly appearance.

Where indigenous, the Pinaster sometimes attains a height of 90 to 100 ft., and a girth of 12 to 15 ft. It has considerable longevity, although not so great as the Black Pines. The largest stem recorded by the Conifer Conference in 1891

[1] Over 125,000 acres of these barren Gascon *Landes* have been planted with the Maritime Pine. Besides improving the national-economic and agricultural capacity of the district, this has given rise to a great industry in timber, and in the manufacture of "*French turpentine.*" Its richness in resin is, however, dependent on a warm climate.

had a height of 68 ft., and a girth of 10 ft. at 5 ft. from the ground. In 1903 the largest known trees were 68 ft. high and 10 ft. in girth (68 years), and 77 ft. high and 9 ft. 10 in. in girth (92 years): both grow in Worcester (Somerville).

Economic Value.—In the south of France and in Spain the wood is much used for such purposes as boards and scantling, packing-boxes, &c. Being of rapid growth, the wood has broad annual rings, but is coarse in fibre; the heartwood is reddish-brown, very resinous, and heavy, though of comparatively little elasticity or durability.

Soil and Situation.—It grows best on a deep, dry sand, or a light loam that is always porous and dry in the subsoil. It does not do well on chalk or any other calcareous soil. With respect to situation, the nearer it is to the sea-level, the better it will grow. As already remarked, it will not thrive in Britain on any inland or lofty situation, as it invariably languishes and dies off prematurely; but near the coast, where the wintry cold is mitigated by the comparatively mild sea air, it is hardy enough.

Cultivation.—The Pinaster begins to produce seed on the *Landes* as early as its fifteenth year. In Britain it is generally grown from French seed. The seeds are somewhat large, and when placed in the bed ought to be covered with about three-quarters of an inch of fine earth. They should be sown about the middle of April; but if the season is late or spring frosts are feared, sowing may be delayed till early in May. The seedlings soon appear, and grow quickly during the season. They should be transplanted into nursery-rows when one year old, and after standing for one year should be transplanted again in May, to stimulate the formation of fibrous roots. At three years of age the twice-transplanted plants are ready for putting out.

The Maritime Pine possesses little sylvicultural interest for Britain, except as a means of forming woods for shelter along coast districts, so as to enable other species of crops to thrive better under their lee.

(6) THE RESINOUS or RED PINE, *Pinus resinosa* Soland.

SYNONYM—*P. rubra* Mich.

Specific Character.—*Leaves* divided into 2 needles, 5 or 6 in. long, straight, stiff, yellowish-green, thickly set on the shoots, compressed, and collected in bunches at the extremities of the branches; *sheaths* nearly 1 in. long, white on the young leaves, but shorter, jagged, and darker with age on the older ones. *Branches* rather naked, straight, open, and reddish-brown, the larger ones on the trunk more distant than those of the Corsican Pine (*P. Laricio*); *buds* long, pointed, and very resinous. *Cones* pale reddish-brown, shining, hard, ovate-conical, rounded at the base, 2 in. long, $1\frac{1}{4}$ in. broad, and with very short footstalks. *Seeds* small, with the wing $\frac{3}{4}$ in. long (Gordon).

Distribution.—Red Pine is indigenous to Canada, Nova Scotia, and the Northern States of America. It is never found growing to a large extent in any particular part of its native forests, but only in comparatively small patches as portions of the crop here and there, and never covering many acres in extent in any one place. It is seldom found intermixed with other Pines, or with any other kinds of trees, but is generally to be met with alone, and always on dry, gravelly, sandy, or rocky soil,—never on flat land with a moist subsoil. It was introduced into Britain in 1756.

Description.—When mature, this handsome Pine may easily be recognised at a distance from other species by the redness of its bark and the tufted appearance of the dense bunches of leaves at the ends of its branches. The leaves are rather like those of the Corsican Pine, only much lighter in colour; and the whole aspect and habit of growth are much more open and light than with the latter. The Red Pine is but little cultivated in Britain, though fine specimens may be seen at Kew and at Castle Kennedy.

Economic Value.—The annual rings formed by this tree are close and fine-grained—which unfortunately indicates a slow rate of growth, so that it does not offer anything like the same prospect of profit as some other Conifers. The wood is very heavy when green, and always contains a large quantity of resin. In Canada it is called "Norway Pine," and in Nova Scotia "Yellow Pine." It is largely imported from Quebec into Britain under the trade name of "American or Canadian Red Pine," and is strong and durable, being used for the same purposes as Scots Pine. It cuts up in fine clean scantlings and planks, very free from knots.

Soil and Situation.—The Red Pine grows best on dry, sandy, or gravelly land, or on good soil formed from rocky *débris.* In Canada it is seldom to be found on any other than sandy and gravelly soil, and on perfectly dry knolls and ridges. In Britain it should therefore be planted on similar soil, and not in low-lying situations with cold or wet subsoil. And it should be planted in the interior of plantations, where it may have shelter from the surrounding trees; for, where indigenous, it is always found sheltered by other trees. It is hardy in our climate.

Cultivation.—The seed of the Red Pine is easily procurable from America. Sowing and transplanting are similar to what has been described for Scots Pine.

(7) THE PYRENEAN PINE, *Pinus Laricio var. pyrenaiça* Loudon.

Specific Character. — *Leaves* divided into 2 needles, rarely in threes, long, rather fine, stiff, straight, and of a bright-green colour, thickly set on the branches, and 6 or 7 in. long, channeled on the inner sides, and sharp-pointed; *sheaths* ½ in. long on the young leaves, smooth, entire at the margins, and dark-brown, but on the old ones very short, shrivelled, rough, jagged, and nearly black. . . . *Cones* 2½ in. long, 1¼ in. wide, conical, tapering a little to the base, on short, slender footstalks, mostly solitary, and pointing horizontal. *Seeds* rather small, with a narrow, pointed wing, ¾ in. long (Gordon).

Distribution.—The Pyrenean Pine is confined chiefly to the Pyrenees, where it grows intermixed with other Pines, and only in dry localities. In France and Spain it occupies the highest mountain-ranges, and even in the north of Scotland it is hardy. It was introduced into Britain in 1834. This and the Calabrian Pine are both closely related to the Corsican Pine and the Aleppo Pine. The botanical distinctions are so slight that Continental botanists regard them as mere climatic varieties of one species; and for a long time doubt existed as to their being anything but more or less constant varieties of the comprehensive species Black Pine (*P. Laricio*).

Description.—The Pyrenean Pine is one of the handsomest species of the genus, growing to 70 or 80 ft. high, with a proportionate girth. It has dense masses of soft, green foliage, is very hardy, and grows quickly. It is easily recognisable from other Pines by its beautiful bark and foliage, and by its cones growing for the most part singly. The leaves are long and fine, but strong and upright, and are arranged round the branches like the hairs of a camel-hair pencil. The branches are stout, and bright orange in colour. The buds are conical, with a long tapering point, and are covered with downy scales, and full of resin. When young it resembles the Aleppo Pine (*P. halepensis*); but when older it grows more rapidly, attains a greater height, and assumes a more pyramidal form. The cones also resemble those of the Aleppo Pine in having strong footstalks; but instead of pointing downwards, they are always horizontal. The largest specimen reported to the Conifer Conference of 1891 was 35 ft. high, and had a girth of 5½ ft. at 5 ft. above the ground.

Economic Value.—The timber is white and dry, and almost non-resinous. It was formerly much used for decking Spanish ships; but it is, on the whole, of inferior quality, and only suitable for ornament.

Soil and Situation.—It grows quickly and well on most dry, loamy soil, thriving best on a light, deep, dry, sandy loam. Although perfectly hardy in our climate, it requires the shelter of other trees to grow to its best.

Cultivation.—The seed is easily obtainable from abroad; and plants can be raised in the same way as those of the Scots Pine.[1]

(8) THE CALABRIAN PINE, *Pinus pyrenaica* Lapeyrouse.

SYNONYMS—*Pinus Paroliana* Webb; *P. Loiseleuriana et pyrenaica* Carr.; *P. Parolinii* Vis.; *P. hispanica* Cook.

Specific Character.—*Leaves* divided into 2 (rarely 3) needles, from 6 to 8 in. long, very slender and wavy, glabrous, spreading, channeled above and convex below, serrulated on the margins, with a sharp point, and of a bright-green colour. *Sheaths* ½ in. long, of an ash colour, quite entire, and not falling off. *Buds* ¾ of an inch long, pointed, woolly, and free from resinous matter. *Cones* stalkless, generally in large clusters, but sometimes singly on young trees, ovate, and smooth, 2 to 3 in. long, and flattened at the base, of a deep-brown colour, and remaining on the tree for years. *Scales* depressed, umbilicate, and slightly concave at the apex (Gordon).

Distribution.—The Calabrian Pine is found in Calabria, Southern Italy, Cyprus, Crete, Asia Minor, and Syria, and is regarded by Continental botanists as a variety of the Pyrenean Pine, both of which were formerly taken to be but climatic varieties of the comprehensive species Black Pine (*P. Laricio*).

Description.—This is a tree of only medium size, with large and spreading branches thickly set with long, bright-green foliage. The bark is of greyish-brown, smooth, and covered with depressed tubercles. It resembles the Aleppo Pine, but is distinguishable by its leaves having nearly twice the length, and by its cones being without stalks, and growing in large clusters. Its habit of growth somewhat resembles that of the Corsican Pine (*P. Laricio*), but its leaves are much more slender, and somewhat longer than those of the latter. It is hardy in most parts of Britain, and forms a handsome ornamental tree.

Economic Value.—Its timber is good, but the tree is only of arboricultural interest here.

Soil and Situation.—It thrives on most dry, light soil, in sheltered situations.

Cultivation.—The seed may be sown on light soil on any sunny piece of ground; but if the soil be very rich, the seedlings grow too rapidly, and become over-sensitive and predisposed to disease. Otherwise the young plants are hardy and accommodating, and are fit for planting out in their third or fourth year, according to the size wanted.

(9) THE MUGHO PINE, *Pinus Mugho* Poir.[2]

SYNONYMS—*Pinus montana* Du Roi and Mill.; *P. pumilio Mughus* Loud.; *P. Mughus* Scop. and Forb.; *P. uncinata* Gand.; *P. humilis* Link.

Specific Character.—*Leaves* divided into 2 needles in a sheath, from 1 to 2 in. long, twisted, rather broad, stiff, and of a dull-green colour. *Cones* 1½ to 2 in. long, ovate and

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[1] Sometimes the seed of this and of other rarer Pines are sown in cold frames or in boxes under glass, but the plants are not so hardy as those grown in the open air.

[2] Under the comprehensive specific name of Mountain Pine (*Pinus montana* Du Roi and Mill.) numerous varieties are now included in one species by Continental botanists and arboriculturists. These varieties include *P. Mughus* Scop., *P. Pumilio* Hänke, and *P. uncinata* Gand., which, however, are usually kept distinct by British nurserymen. The *P. uncinata* has been extensively planted in Denmark during the last thirty years on dunes and moors. On heaths where previous attempts with Spruce, Scots Pine, and Austrian Pine had failed, Mountain Pine has proved serviceable *as a first crop*, paving the way for the more valuable trees. When planted with Spruce, it has been found to spread and kill the heather, when the Spruce has a fairer chance of growing well.

stalkless, growing 2 or 3 together, rather erect, with hooked scales, more fully developed on the outer side, and full of resinous matter. *Branches* ascending and numerous, thickly covered with foliage, and with a greyish-brown bark (Gordon).

Distribution.—The Mugho Pine is found on the mountains extending from the Pyrenees eastwards to the Alps of Central Europe. This particular species (introduced into Britain in 1785) is more especially to be found in the drier localities of the Pyrenees and the southern Alps, whilst the other species of Mountain Pine, the *P. Pumilio*, is more common on marshy land in the colder northern Alps, Bohemia, and the Black Forest.

Description.—The Mugho Pine is low, spreading, and dwarfish, being seldom more than 20 to 25 ft. high, and often only a mere bush. It is distinguishable from other Pines by its numerous ascending branches, which are thickly covered with dark-green foliage, and by its forming a large bush or scrubby, stunted tree consisting of many side-leaders without any main axis. It is nothing more than a quaint shrub-like Pine, but useful for providing ornament and cover for game on high hills near the limit of tree-growth, and suitable for forming a protective fringe along the outer edge of wind-swept woods and plantations. The largest specimen reported to the Conifer Conference in 1891 had a height of 24 ft., and a girth of 2 ft. 10 in. at 5 ft. above the ground.

Soil and Situation.—It can be grown wherever Scots Pine grows, and ascends the hills still higher; but it is only on good, deep, sandy loam, and at a lower elevation, that it assumes a tree-like habit of growth.

Cultivation.—It is grown from seed in the same way as the Scots Pine. The ripe cones should be collected early in autumn, as they often open and scatter the seed before the end of the year.

(10) THE DWARF or MOUNTAIN PINE, *Pinus Pumilio* Hänke.[1]

SYNONYMS—*Pinus montana* Walth.; *P. Mughus var. Pumilio* Koch; *P. sylvestris var. Pumilio* Gand.; *P. magellensis* Schouw.; *P. uliginosa* Neum.

Specific Character.—*Leaves* divided into 2 needles in a sheath, curved, short, stiff, somewhat twisted, thickly set on the branches, from 2 to 2½ in. long, with long, lacerated, woolly, white *sheaths* when young, but which afterwards, as they get older, become much shorter, and dark-brown, or nearly black. *Cones* from 1½ to 2 in. long and ¾ in. broad near the base, two or three growing together, pendulous, of a dull-brown colour, and bluntly egg-shaped. *Scales* about the size of those of the Scots Pine, but not so much elevated in the centre. *Branches* turned upwards, and very numerous, forming a dense bush, with the lower branches creeping on the ground, but growing, in favourable situations, into a small tree from 20 to 30 ft. high, with a grey and rather smooth bark (Gordon).

Distribution.—The Dwarf Pine is found on the mountains of Central Europe, on the southern slopes of the Alps towards the east on swampy soil, between 4000 ft. and 7500 ft. elevation. It also grows on the northern slopes of the Alps, and is common on the Carpathians, where it occupies a region above the Common Spruce; but at great elevations it is merely a stemless, spreading bush creeping along the ground. It was introduced into Britain in 1779.

Description.—This species of Mountain Pine is a handsome evergreen shrub rather than a tree. It varies from about 12 to 20 ft. in height in different parts of the British Isles, and is chiefly of interest from the contrast it offers in appearance to most other Conifers. It closely resembles Scots Pine of low dwarfish growth (hence one of its synonymous botanical names, *P. sylvestris var. Pumilio*); but it is

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[1] With regard to the distribution of this species and its relation to the Mugho Pine, with which it forms the comprehensive species *Pinus montana*, see also the detailed description of the preceding tree.

somewhat darker in foliage, and the leaves are also much more thickly set on the branches, while the sheaths of the current year's leaves are much longer and whiter, especially towards the extremities of the shoots. Further, it seldom makes shoots of more than 4 in. in length in any one season, and if a branch be broken, a fluid resin exudes with a fragrant aroma, differing from the resinous smell of other Pines even of this same Pinaster class.

Soil and Situation.—It is a very hardy species, which will grow wherever the Scots Pine can. It attains its best development in the shelter of other trees, as along the sides of roads through plantations.

Cultivation.—The cones should be gathered and the seed sown in the same way as with the Scots Pine; but the seeds, being smaller, should have a lighter covering of earth.

Along with the Mugho Pine (which equally deserves the name of *Mountain Pine*) this Dwarf species is of great importance in Alpine districts, where it forms the upper limit of tree-growth in the "**ban-forests**" maintained as State property for the prevention of the formation of avalanches, and for the protection of the agricultural lands lying far off in the plains below. In the Tyrol and Vorarlberg alone, more than 77,000 acres are stocked chiefly with these Mountain Pines, whose spreading, tough branches and dense foliage keep back the snow, and whose root-systems bind the soil while it is sodden with rain or melted snow.

(11) THE JERSEY or SCRUB PINE, *Pinus inops* Soland.

SYNONYMS—*Pinus variabilis* Lamb; *P. virginiana* Mill.

Specific Character.—*Leaves* divided into 2 needles, short, rigid, and sharp-pointed; from 2 to 2½ in. long, bright-green, and scattered equally all over the younger branches. *Sheaths* short, entire, and about ¼ in. long. *Branches* irregularly placed on the stem, twisted, with the more slender branchlets pendulous, and the young shoots covered with a fine, violet, glaucous bloom. *Buds* blunt-pointed and resinous; the stem and larger branches emitting tufts of leaves or abortive shoots. *Cones* oblong-conical, tapering slightly to a blunt point, and drooping; from 2¾ to 3 in. long, and 1¼ in. broad, very hard, and of a glossy yellowish-brown colour, with short, thick footstalks, and usually solitary. *Scales* elevated, pyramidal, 4-sided, terminating in an awl-shaped, strong, projecting prickle, pointing outwards or slightly reflexed, ½ in. broad, and nearly all of a size. *Seeds* very small, with a narrow wing, rather more than ½ in. long. *Seed-leaves* from 6 to 8 in number (Gordon).

Distribution.—The Scrub Pine is found abundantly in most of the North American States from the Hudson River southwards into Carolina, and especially wherever the soil is poor and sandy. There it grows to from 15 to 40 ft. in height. In the barren tracts of New Jersey it covers large tracts of waste land known as the "**Pine Barrens.**" It was introduced into Britain in 1739.

Description.—It is a low tree with twisted branches, the more slender of which are pendulous. The wood of the current year's shoots is glaucous and tinged with violet, a peculiarity of this species, while the stem and larger branches produce small tufts of leaves or abortive shoots. The branches grow irregularly from the stem, and not in whorls, so that it has more the look of a deciduous tree than is common among the *Abietineæ*. The bark of old trees is deeply furrowed, and resin exudes through the fissures in such abundance as to give the stem and branches a sugar-candied appearance. Old trees are almost covered with the exuding resin, which emits a pleasant balsamic fragrance during sunny weather.

It is of no sylvicultural use in Britain, though its quaint form and delightful fragrance make it worth cultivating from an ornamental point of view. But, of course, in the cooler climate of Britain the resin does not exude nearly so plentifully as in America. It grows here to a height of about 30 ft.

Soil and Situation.—It will thrive here on most dry, light lands, but does best when planted in the shelter of other trees, as along the sides of roads in plantations.

Cultivation.—The seeds should be sown on fine, dry, well-prepared ground; and, as they are small, they should only be covered very lightly with soil.

(12) BISHOP'S PINE, *Pinus muricata* Don.

SYNONYM—*Pinus Edgariana* Hartweg.

Specific Character.—*Leaves* divided into 2 needles, not very thickly set on the branches; from 3½ to 4 in. long; very stiff, rather broad, blunt-pointed; hollow on the inner side, round on the outer, and of a deep-green colour. The *sheaths* are rather short, smooth, and not more than ½ in. in length on the young leaves, and only slightly persistent on the older ones. *Seed-leaves* on the young plants in fives, and rather short. *Branches* not very numerous, but tolerably stout, and rather irregular. *Buds* below the middle size, imbricated, much pointed, and destitute of resinous matter. *Cones* in clusters of from 4 to 7, and set in whorls round the stem. They are reddish-brown when young, but change to a grey or ash colour when old; somewhat pendulous, and nearly straight, or very slightly incurved on the side next the branch; 3 in. in length, and 1½ in. broad near the base, and tapering to rather a blunt point. The base is slightly uneven, and the cone sessile, or nearly so. *Scales* largest on the outer side of the cone, particularly those near the base, where they are conical, nearly straight, or slightly bent backwards near the base, much elongated, pointed, and ½ in. in length; the scales on the inner side of the cone, and at the point, are much the smallest, quadrangular, and nearly flat, except those near the point, which are rather more elevated than the others, with a slight ridge running across their middle, terminated by a short, straight, broad prickle in the centre: each cone contains from 9 to 10 rows of scales, within each of which are two very small dark-brown seeds, with wings ½ an in. long (Gordon).

Distribution.—This Pine was first discovered by Coulter at San Luis Obispo, in Upper California, to the south of Monterey, at an elevation of 3000 ft., and within ten miles of the sea-shore. Hartweg also found it growing on the western declivity of the mountains near Monterey, and within three miles of the sea-shore. Jeffrey found it on the Siskyon Mountains, in California, at an elevation of 7500 ft., growing in moist soil near the summit. It was introduced into Britain in 1846.

Description.—Bishop's Pine is rather a dwarfish, stunted kind of tree, seldom above 40 ft. in height, and with a stem about 12 in. in diameter. At first glance it looks much like the Remarkable Pine (*Pinus insignis*), but on closer inspection is seen to be quite a distinct tree. It is hardy and ornamental, and is suitable for planting in parks and along drives in woodlands.

Economic Value.—It has no sylvicultural value for Britain, but is merely ornamental.

Soil and Situation.—It grows well on any good light soil; but in our climate it requires a sheltered situation, with free exposure to light and air. It does not stand confinement among larger trees.

Cultivation.—Even in California it is not very plentiful, so that seeds are comparatively scarce. As the seeds are small, they should be sown about the end of April or early in May, on finely prepared soil, and but lightly covered with earth. The seed-bed should be shaded by a canvas cloth or sun-shade stretched over it, or covered with an awning of Spruce branches, to prevent sun and rain from injuring the seeds before they germinate. As soon as the seedlings appear, however, the awning should be gradually removed during dull weather; otherwise any sudden change from shade to sunshine is apt to kill off a large proportion of the delicate seedlings.

(13) THE PERSIAN PINE, *Pinus persica* Strangways.

Specific Character.—*Leaves* divided into 2 needles, twisted, rather stiff, sharp-pointed, and not spreading; dense, and tufted towards the ends of the branches; of various lengths, from 2 to 5 in. long, deep-green, channeled on the inner side, and convex on the outer one, with the edges rough and finely serrated; seldom remaining longer on the tree than the second year. *Sheaths* persistent, short, ⅓ of an in. long, rather smooth, but shrivelled, not jagged at the ends, and guarded at the base with rather a broad, lanceolate, recurved scale, of a bright-brown colour, although green at first. *Cones* ovate, tapering to a very blunt point, and rounded at the base, 5 in. long and 3 in. across at the widest part; mostly in clusters round the stem or principal top branches, but frequently solitary, and pointing downwards; of a dull greyish-brown colour, with a hard smooth surface, short footstalks, and destitute of resinous matter. *Scales* slightly elevated, nearly 1 in. broad, with apex depressed, and hollowed in the centre. *Seeds* large, with a broad wing 1½ in. long. *Branches* regular, short, and rather slender, but mostly pointing upwards; the larger and older branches rather naked on the lower parts, but tufted with leaves towards the points. *Buds* imbricated, very thready, and free from resin (Gordon).

Distribution.—This is a very doubtful species, imperfectly known, and is probably merely a climatic variety of *P. pyrenaica* or *P. halepensis.* Staph, who collected in South Persia, was never able to recognise it. It was introduced into Britain by the Hon. W. F. Strangways from the south of Persia.

Description.—It very much resembles the Aleppo Pine, but is distinguishable by its longer and stiffer leaves, and by their being somewhat twisted. The cones are also much larger. And whilst the latter is generally of low and spreading habit, the Persian Pine is of a freer development, attains large dimensions, and is tolerably hardy.

Economic Value.—Although hardy enough to grow as an ornamental tree in warm, sheltered situations, it is unsuitable for even moderately elevated or exposed sites, and it is only of arboricultural interest.

Soil and Situation.—It does best on a deep, dry, light loam, and in a warm and sheltered situation.

Cultivation.—The seed should be sown on light, dry soil, in a warm situation, and shaded till the young seedlings appear, after which they should gradually be exposed to the light and air. The seeds are sometimes sown in a cold frame, and the seedlings transplanted when one year old. The young transplants require to be protected under a frame during the first winter.

(14) THE STONE PINE or UMBRELLA PINE, *Pinus pinea* L.

Specific Character.—*Leaves* divided into 2 needles, from 5 to 8 in. long, straight, very robust, and of a deep shining green colour. On young plants they consist of a glaucous single bract-like leaf, thickly set on the shoots, and without any sheaths, and from amongst which afterwards spring the true leaves. *Sheaths* when young ½ in. long, but afterwards they become torn, and reduced to half their size. *Cones* from 5 to 6 in. in length, and nearly round or bluntly ovate, of a pale-brownish glossy colour, very solid, and not coming to maturity till the third year. *Scales* large, from 2 to 2½ in. in length, and 1½ in. broad, with the thickened part pyramidal, and frequently 6-sided, but mostly having but 4 ribs, from the 4 angles, which terminate in a blunt prickle. *Seeds* very large, ¾ in. long, with rather a broad but very short wing. *Seed-leaves* from 9 to 10 in number (Gordon).

Distribution.—This is a native of Italy, Spain, Greece, the coast of Barbary, and some parts of Western Asia. It is also found wild in the south of France, but it is doubtful if it is indigenous there, as it never forms forests, and very rarely woods of any considerable extent. It is also to be found on the Canary Isles and in Madeira, although there, too, it is probably not of spontaneous growth. It was introduced into Britain about 1548.

Description.—In Britain it attains only 20 to 25 ft. in height, and has a rounded, bushy appearance. Its long leaves and round cones produce a fine effect on old trees. The branches are spreading, and when old are well clothed with deep-green foliage: the whole forms a round or bushy tree, with a reddish bark, which is generally cracked and furrowed. It is often mistaken for the Cluster Pine, as the leaves of the two are very much alike. Their habit of growth is, however, quite distinct; for the Cluster Pine grows up quickly into a large tree of open form, while the Stone Pine always remains a large-spreading, densely foliaged bush or dwarfish tree. Old trees are at once distinguishable by their cones; for in the Stone Pine they are round, while in the Cluster Pine they are conical.

Where it is indigenous, the Stone Pine can attain a height of 100 ft. and a girth of 16 to 20 ft., although these dimensions are unusual. It can there also attain an age of over 500 years. It begins to produce seed about the age of twenty years, and is most prolific between its fortieth and sixtieth years. The largest specimen reported to the Conifer Conference in 1891 had a height of 30 ft., and a girth of 4 ft. at 5 ft. above the ground.

Economic Value.—The wood is whitish, moderately resinous, and very light. It is used in Italy and in the south of France for general carpentry and joinery; but in Britain the timber is of little or no use, and the tree can only be cultivated for its æsthetic effect. Like the two Mountain Pines, it answers well for hiding objects immediately behind it, as it forms a dense bush compactly clothed with its long leaves and beautifully rounded and shining cones. Even where indigenous, the Stone Pine is valued chiefly for its fruit. Its edible seed or "**Pine-nuts**" are sold throughout the towns of Upper Italy, where they are brought to market in large quantities. One forest alone near Ravenna—now destroyed—yielded on the average 6000 bushels of Pine-nuts annually. In this respect the Stone Pine resembles the Gerard Pine (*P. Gerardiana*) of Northern India.

Soil and Situation.—This tree grows best on a deep, light, dry soil, and in a warm, sheltered situation. Planting should not be close; for the tree is light-demanding, and when planted thickly it soon loses its natural characteristics.

Cultivation.—The seeds of the Stone Pine have a very thick shell. They are generally sown in boxes in winter, and sheltered under a frame till spring, the earth being kept rather moist to soften the shell. In summer most of the seeds will come up, although others may probably remain without germinating till the second year. Some prefer to break the shells of the seeds before sowing them; but this is apt to destroy the germinative power. The plants are very tender during the first two years, and require to be kept under glass frames in winter. When one year old the seedlings should be transplanted into the open nursery-beds, and merely covered with a frame during winter. When three years old they will be quite hardy enough to stand our winter, and may be planted out. Like the Cluster Pine, it has a long tap-root, and many cultivators therefore grow it in pots singly, thereby avoiding the annual transplanting which is necessary in order to stimulate the development of fibrous roots.

(15) THE ALEPPO PINE, *Pinus halepensis* Mill.

Synonyms—*Pinus maritima* Lamb.; *P. Pithyusa* Strangw.; *P. arabica* Sieb.; *P. Abschasica* Fisch.

Specific Character.—*Leaves* divided into 2 needles, but sometimes in threes, of a deep-green, from 2½ to 3 in. long, thickly set on the younger branches, and very slender, not remaining longer on the branches than two years, in consequence of which the branches of old trees have a naked appearance, and the head an open, thin, and straggling aspect. *Buds* ¼ of an inch long, imbricated, roundish, and entirely destitute of resin.

Cones pyramidal, rounded at the base, smooth, solitary, or in pairs, 2½ to 3 in. long, and 1½ in. broad, inversely turned downwards, with a footstalk ⅜ of an inch long (Gordon).

Distribution.—The Aleppo Pine is to be found from the western coast of Portugal eastwards into Arabia and Armenia, but chiefly in the tracts bordering the Mediterranean Sea. It is much more closely related to the Pyrenean Pine than any other species; but while that forms woods in Western Europe, the Aleppo Pine forms forests, often pure, on the Taurus Mountains in Asia Minor, and on the Balearic Isles. Its finest development, however, is said to be attained on the Lebanon range, where it attains large dimensions. It is always found on dry, sandy, warm soil, and thrives well even among rocks, where few other trees could prosper. It was introduced into Britain in 1683.

Description.—It is a low, spreading tree, seldom above 40 ft. high, except under very favourable circumstances. It is not a hardy species in our climate, and has therefore been but little planted. Fair specimens of it are now common in England, and some are over 50 ft. in height, with stems over 15 in. in diameter. The young tree soon forms a spreading head with slender branches, and those of the last two years' growth are clothed with fine, deep-green foliage, giving a soft and wavy appearance. Old trees, however, have a naked, straggling look, as the foliage is never persistent for longer than two years.

Economic Value.—The wood is white and fine-grained. Where the tree attains large dimensions, the wood is considered superior, and is used for building purposes. As the wood is very resinous, it is used as torches by fishermen on the Istrian coast; and as the bark is rich in tannin, it is used for dyeing. But in Britain it is merely an ornamental species grown in favourable situations.

Soil and Situation.—Here this tree requires a light, dry soil, and a warm, sheltered situation. It does not thrive on rich soil, which stimulates it to too rapid growth, when the young shoots get frost-bitten in winter. It is better to grow it on a poor, dry, light soil, where it ripens its branch-wood better during the summer months.

Cultivation.—The seed should be sown in a warm spot, and the plants covered with a frame during the first two or three winters, till they are sufficiently large and hardy for planting out.

(16) BANKS' PINE, *Pinus Banksiana* Lambert.

Specific Character.—*Leaves* divided into 2 needles, very closely pressed together, about 2 in. long, light-green. *Buds* of a long oval shape, resinous. *Young shoots* at first green, then brown, smooth. *Cones* about 2 in. long, and less than 1 in. broad, slightly bent, pointing upwards, and pressed close to the twig. *Seed* small, and seated in a spoon-shaped hollow of the wing (as in Spruce).

Distribution.—This is a native of the colder part of Eastern America below 68° S., where it grows on the poorest inland soil.

Description.—On poor land it only grows to from 35 to 50 ft. high, but reaches a height of 70 to 75 ft. on good land. It has a wide-branching root-system, and has somewhat of the habit of a Spruce in not being able to shed its branches quickly like most other Pines.

Economic Value.—This hardy Pine is said to be one of the most valuable of the trees recently introduced from North America, on account of its being able to thrive on the poorest classes of soil, such as dunes and shifting sand, where the Scots Pine cannot maintain itself. It grows quickly at first, especially about the third year after planting, when it seems to establish itself thoroughly. Its timber is said to be of much the same quality as Scots Pine.

The results of experiments in Germany show that it is very accommodating as to soil, rapid in growth, and hardy against frost and drought, being in all these respects superior to Scots Pine. It makes two good shoots during the year, and even three under favourable circumstances.

Cultivation.—As for Scots Pine.

II. TERNATE PINES, HAVING USUALLY THREE NEEDLES IN EACH LEAF-SHEATH.

(1) GERARD'S PINE, *Pinus Gerardiana* Wallich.

Specific Character.—*Leaves* divided into 3 needles, stiff, three-edged, stout, and bluntly terminating in a short point, from 3 to 5 in. long, of a bluish-green colour, and glaucous when young. *Sheaths* short at first, and composed of dry, reddish-brown scales, but soon rolling up and falling off. *Branches* ascending, but the lower ones spreading, and the branchlets short, somewhat slender, and irregularly disposed. *Cones* of a bluish colour, ovate, oblong, or somewhat cylindrical, widest at the base, from 6 to 8 in. long, and from 12 to 15 in. in circumference near the base. *Scales* thick, blunt, much recurved and spiny at the points. *Seeds* nearly 1 in. long, cylindrical, almost wingless, pointed at both ends, of a dark-brown colour, and agreeable to eat (Gordon).

Distribution.—Gerard's Pine is found, beyond the influence of the periodical rains, on the northern side of the Snowy Range of mountains in Kunawur, where it grows on very dry rocky ground. It is also found to the north of Cashmere, and on the Astor Mountains in Little Thibet. Gerard found its limits on the inner Himalayas to be from 10,000 to 12,000 ft. above the sea-level. It was introduced into Britain in 1815.

Description.—It is a tree of conical shape and of large girth, but no great height. It is recognisable from all the other three-leaved Pines by its scaly sheaths, which soon fall off, and by its smooth, silvery-grey bark, which it sheds in silky flakes. It is a very slow-growing tree, but tolerably hardy, and distinctly ornamental.

Economic Value.—Even where indigenous, no particular value is attached to its wood. In any case, it is only of arboricultural interest in Britain.

Soil and Situation.—It does best on a light and dry soil and in a warm, sheltered situation. Like all other Pines, it needs a clear, pure air; but it is much more sensitive than most of them, and in smoky atmosphere merely dwindles away. Healthy plants cannot even be raised in nurseries near smoky towns.

Cultivation.—The seeds are an article of food in Northern India, just as the "**Pine-nuts**" of the Stone Pine are in Italy. The seeds best retain their germinative power if brought here in the cone. They germinate freely in a light, friable soil; but the young plants usually require protection during the first winter. After being transplanted, however, they become more hardy; and in favourable situations they soon become stout, strong, and fit for planting out in places sheltered from wind.

(2) THE LARGE-CONED PINE, *Pinus Coulteri* Don.

SYNONYMS—*Pinus macrocarpa* Lindl.; *P. Sabiniana var. Coulteri* Loud.

Specific Character.—*Leaves* divided into 3 needles, stout, and rather stiff, from 9 to 12 in. long, and of a glaucous-grey colour, ribbed on the inner side, rather flat, incurved, pointed and compressed. *Sheaths* ragged, thready, persistent, 1½ in. long on the young leaves, but shorter and torn on the old ones. *Branches* stout, rather distant, but regularly placed in whorls on the stem, nearly horizontal, slightly elevated towards the extremities, and tinged with violet on the young shoots. *Cones* conical-oblong, tapering to the point, solitary, very large, 12 to 14 in. long and 6 in. broad, very hard, smooth, pale-yellow, with a polished surface, and frequently weighing from 3 to 4 lb. each (Gordon).

Distribution.—This species is indigenous to California and the mountains of Santa Lucia, near the Mission of San Antonia, within sight of the sea, at an elevation of from 3000 to 4000 ft. It was introduced into Britain in 1832.

Description.—In its native country it attains a height of 80 to 100 ft., with a stem of 3 to 4 ft. in diameter. It is easily known from all other Pines by its very large cones, by its long foliage, by its nearly horizontal branches, far apart from each other, and by the violet tinge of the bark on the young shoots. It is a much-admired species, as its long leaves contrast well with more densely foliaged trees; whilst the glaucous grey of its foliage is seen to great advantage against other trees of a darker colour. The largest specimen reported to the Conifer Conference in 1891 was 44 ft. in height, and 4½ ft. in girth at 5 ft. above the ground.

Economic Value.—This tree has only the beauty of its foliage and the unusual size of its cones to recommend it; it is of no sylvicultural value.

Soil and Situation.—Although hardy, and found to grow well in many parts of Britain, it is somewhat exacting as to soil and situation. It requires a good, deep, dry, light loam, an open, dry subsoil, and a situation that protects it from the morning sun. Trees of this species are often found to lose their tops from the action of the sun's rays on them in the early part of the day, after a night's frost in late spring; but where such exposure can be prevented, the trees do well, keep their leaders entire, and form good ornamental specimens.

Cultivation.—Like the Stone Pine, seedlings of this species require the protection of a frame during their first winter; but after being transplanted into the nursery, they are hardy enough to stand there in all parts of Britain having a mild winter climate.

(3) THE CHINESE LACE-BARK PINE, *Pinus Bungeana* Zucc.

SYNONYM—*Pinus excorticata* Gordon.

Specific Character.—*Leaves* divided into 3 needles, very stiff, convex on the back, and acutely keeled on the inner face, from 2 to 3 in. long, and thickly set on the branches, frequently in bundles towards the ends of the shoots, somewhat in whorls, and irregularly three-edged. *Sheaths* composed of numerous loose scales, which soon fall off and leave the base of the leaves naked. *Buds* non-resinous, and formed of several reddish-brown, smooth, fringed scales, largest at the base, and rough at the edges. *Male catkins* from 5 to 6 lines long, cylindrical or conical; when young, placed alternately at the base of the young shoots, but frequently afterwards very distant, owing to the rapid elongation of the young shoot. *Branches* long, very slender, little divided, glaucous, and covered with a smooth grey bark, rendered a little rough on the stem and older branches by the transverse scars forming rhomboidal-shaped figures, which in due time are shed, and give the stem and branches a very peculiar appearance. *Cones* ovate or slightly conical, broadest near the base, 2½ in. long and 1½ in. diameter, and obtuse-ended (Gordon).

Distribution.—This is a native of Northern China, and was introduced into Britain in 1846. It is cultivated by the Chinese as the "**Lace-bark Pine.**"

Description.—It is hardy, and grows from 30 to 50 ft. high. The bark of young plants resembles the skin of a pea more than that of a Pine-tree; but as it grows older the thin outer cuticle peels off in silk-like scales, leaving the branches and stem with a greyish-white surface. Another peculiar characteristic is that the new leaves of young shoots are at first furnished with perfectly formed sheaths, which soon fall off, leaving the leaves sheathless, in the same way as the outer bark falls off the stem and branches. It is only of arboricultural interest as a strange species.

Soil and Situation.—Although coming from the coldest and poorest districts of China, where the summers are intensely hot, it is quite hardy in Britain, and fairly accommodating as to soil and situation. But it does best on a light, dry soil, and in a sheltered situation, where it is least exposed to the sudden variations of our changeable climate.

Cultivation.—The seed is very scarce, as it must be obtained from North-western China. The seeds germinate readily when sown in the usual way, and the plants soon become fit for planting.

(4) THE HEAVY-WOODED or YELLOW PINE,
Pinus ponderosa Dougl.

SYNONYMS—*Pinus brachyptera* Englm.; *P. nootkaensis* Man.; *P. Parryana* Gord.; *P. Beardsleyi* Murr.; *P. Craigiana* Hort.

Specific Character.—*Leaves* divided into 3 needles, from 8 to 10 in. long, twisted, rather broad and flexible, thickly set on the branches, sharp-pointed. *Sheaths* 1 in. long, smooth, but much shorter and shrivelled on the old leaves. *Branches* few, in regular whorls, robust, twisted, and somewhat drooping. *Buds* bluntly domed, with a prominent point, and full of resin. *Cones* straight, ovate, tapering to both ends, particularly towards the apex, $3\frac{1}{2}$ in. long and $1\frac{3}{4}$ in. broad; in clusters round the branches, on very short stout footstalks, and bent downwards (Gordon).

Distribution.—The Yellow Pine is plentiful on the north-west coast of America, from California southwards into New Mexico, and particularly on the banks of Spoken River and the Kettle Falls of the Columbia, west of the Rocky Mountains, as well as in Rose River valley in California. It was introduced into Britain in 1826.

Description.—As this tree grows old it is remarkable for its twisted branches, which are disposed in regular verticillate whorls. It generally grows to a height of 60 to 100 ft., with few branches, and a large girth. In eastern Nebraska this is called the "**Bull Pine.**" According to Engelmann, it attains gigantic dimensions, resembling those of the Douglas Fir and the Menzies Spruce in the Rocky Mountain forests. The largest specimen reported to the Conifer Conference in 1891 had a height of 63 ft., and a girth of 9 ft. 2 in. at 5 ft. from the ground. The largest known in 1903 (74 years, in Bucks) is 98 ft. high and 8 ft. 5 in. in girth. It was grown from seed sent home by Douglas in 1827 (Somerville).

Economic Value.—In California, the home of many species of gigantic Conifers, the heavy wood of the Yellow Pine is said to be of excellent quality and very durable. It has a high specific gravity, and almost sinks in water. The timber produced here is coarse-grained, but strong; and as the tree is hardy and quick in growth, it may perhaps prove worth cultivating for profit.

Soil and Situation.—It has been found to do well in Britain on poor gravelly soil or sandy loam. On a rich soil the plants generally grow too luxuriantly, and do not ripen the woody tissue of the points of their shoots sufficiently to enable them to resist the frosts of our winter. It does best on an airy but not exposed position.

Cultivation.—The seed may be sown and the seedlings reared in the usual way, as they are quite hardy and easy of cultivation: it is well, however, not to grow the young plants where late frosts are common.

Sylvicultural Characteristics.—Continental experience of the Yellow Pine as a forest-tree shows that it is decidedly accommodative as to the mineral nature of the soil, but that it thrives best on a deep loamy sand. Although at first of rapid growth, it afterwards develops more slowly. Experiments might probably show that this is a Conifer which could be cultivated with profit in Britain. It does not appear to be able to stand the winter cold of the Continent, and is there said to be liable to be attacked by the fungous disease (*Lophodermium pinastri*) causing "*leaf-shedding.*"

(5) BENTHAM'S PINE, *Pinus Benthamiana* Hartweg.

SYNONYM—*Pinus Sinclairii* Hooker. It is now generally referred to *P. ponderosa.*

Specific Character.—*Leaves* divided into 3 needles in each sheath, thickly set on the branches, dark-green, and resembling those of the Yellow Pine, but much longer, usually 11 in. in length, very stout, rather flat, with a slightly elevated rib running along their inner side. *Sheaths* partly persistent, and nearly 1 in. long on the leaves of the young shoots, slightly shaggy, except at the extremity, where they are very ragged or torn. *Branches* rather numerous, very stout, spreading, and somewhat irregular, with a rough bark. *Buds* large, dark-brown, much imbricated, and generally free from resinous matter, although sometimes there is a little. *Cones* in clusters of from 3 to 5 together, slightly pendulous, and quite straight, 6 in. in length, and 2½ in. broad at the widest part, which is rather below the middle; the base is unequal-sided, owing to the numerous very small *scales* there curving to one side and forming a kind of hood round the base of the cone, which is quite sessile (Gordon).

Distribution.—This Pine was first met with on the mountains of Santa Cruz (California), a coast-range running due north across the bay from Monterey; afterwards it was found in the Sacramento country, growing upon the ridge generally termed "The Californian Mountains." It was introduced into Britain in 1847.

Description.—This noble species of Pine, which grows to 200 ft. high and 9 to 10 ft. in diameter, is entirely a tree of the mountains. It resembles the Yellow Pine while young, but is distinguishable by its longer leaves. On twigs of young trees about 15 ft. high the leaves often average nearly 10 in. long; while similar specimens taken from the Yellow Pine are only from about 7 to 8 in. long.

Economic Value.—The timber is somewhat lighter and more elastic than that of the Yellow Pine, and is said to be even more durable. This is one of the Pines which might possibly be grown here with profit; but as it is both hardy and ornamental, it is at any rate worthy of a place in parks and policies.

Soil and Situation.—This species is decidedly accommodating. It can be grown on any soil that is deep and dry, and not heavy or clayey. It does well on most light loamy soil, and even in moderately exposed situations makes annual shoots about 2 ft. long.

Cultivation.—It may be raised in the same way as the Scots Pine.

(6) THE STIFF-LEAVED or PITCH PINE, *Pinus rigida* Mill.

SYNONYMS—*Pinus canadensis trifolia* Duham.; *P. Taeda rigida* Ait.; *P. Loddigesii* Loud.

Specific Character.—*Leaves* divided into 3 needles in each sheath, from 3 to 4½ in. long, stiff, rather broad and sharp-pointed, light-green, and spreading. *Sheaths* short, ⅜ of an in. long, and white on the young leaves, but afterwards becoming nearly black and shrivelled. *Branches* very numerous on the upper part of the tree, and compact. *Cones* ovate-oblong, from 2½ to 3½ in. long, and 1½ in. broad, on short stout footstalks, in clusters of 4 or 5 round the top branches, and remaining on the tree for years (Gordon).

Distribution.—The Pitch Pine occurs in most parts of the United States, from New England southwards to Virginia, and is found growing both on dry and on wet soil. Although found on sandy and marshy soil in many of the inland tracts of North America between latitude 38° and 44°, its finest growth as a true forest-tree is in the Alleghany Mountains, where it often forms extensive woods. In America it is called the "Pitch Pine," owing to the abundance of resin it contains. It was introduced into Britain about 1750.

Description.—In America this tree grows to a large size. On light, sandy lands in the State of Pennsylvania it attains over 80 ft. in height, with a stem of fully 2 ft. in diameter. Good trees may also be found on wet ground at the edge of swamps; but on poor high-lying tracts it is only a large-headed bush. Old trees have a thick, dark, coarse, deeply-furrowed bark, and generally a very branching habit of growth. They seldom form a clean stem, even when growing in masses or among other trees; and their wood is consequently very knotty. It cannot be said to be a highly ornamental tree, nor is its timber valuable; but it is hardy and very accommodating as to soil and situation, and is therefore well adapted for planting where variety is desired.

Economic Value.—In Britain it is of no economic value, the tree being grown merely for its arboricultural interest. In America the durability of the timber[1] depends on the soil on which the trees are produced, and the grain is usually coarse. When grown on the mountains, its wood is very resinous and durable; whereas the "Sap Pine" wood produced on low-lying marshy land is soft and of little value.

Soil and Situation.—Few Pines are more accommodating than this one in respect to soil and situation. To grow well, however, it requires a light, friable, deep soil, and a situation not too much exposed. Even where indigenous, it is a tree of the inland tracts, and not of the sea-board stretches having a damp climate.

Cultivation.—This is in all respects the same as with the Scots Pine. Plants are now easily obtainable from nurserymen at reasonable prices.

Sylvicultural Characteristics.—Experiments conducted during the last sixty years in the Prussian State forests show that this species of Pine, when treated as a forest-tree, has a very marked resemblance to the Common Pine. It is somewhat quicker in growth at first, but is caught up at about ten years of age; and at fifty years of age the trees are not above 50 ft. in height. But it is as hardy as Scots throughout Pomerania and Silesia, and has a stronger recuperative power in healing wounds inflicted by game, &c. It may therefore possibly be of some sylvicultural interest for the Highlands of Scotland, as it can thrive both on dry and on marshy soil, although, of course, it grows best on tracts that are merely fresh or at most moist. Like the

[1] This is not the heavy, strong timber imported largely into Britain from America under the trade name of "Pitch Pine" or "Georgia Pitch Pine," which is the wood of the long-leaved Marsh Pine (*Pinus palustris*) of the Southern States, and is largely used for beams, roofing, stairs, carriage-building, and engineering works.

Scots Pine, it is a *light-demanding* species of tree. On the poorer classes of sandy soil throughout Northern Germany it has been found to be perhaps preferable to the Scots Pine, although, of course, under such very unfavourable circumstances it is also exposed to danger from excessive drought. There seems to be a consensus of opinion that Pitch Pine makes very small demands on mineral food-supplies, and that it can thrive where the Weymouth and the Mugho Pine fail. And it grows in such places much better than the Scots Pine. It suffers less from "leaf-shedding," stands frost and exposure well, grows quickly, and transplants easily as it forms good roots. It throws up stool-shoots, and is much used in forming coverts for game (Schwappach).

(7) THE RADIATED CONE PINE, *Pinus radiata* Don.

SYNONYM—*Pinus insignis var. macrocarpa* Hartweg.

Specific Character.—*Leaves* divided into 3 needles in each sheath, very slender, twisted, deep-green, thickly set on the branches, and from 3 to 5 in. long. *Sheath* short, smooth, ¼ of an in. long on the young leaves, but much shorter on the older needles, and only partially persistent. *Seed-leaves* on the young plants from 7 to 8 in number, rather long and slender. *Branches* compact, numerous, rather regular, and slender, particularly the lateral ones. *Bark* light-brown, and rather smooth. *Buds* small, numerous, imbricated, and full of resinous matter. *Cones* mostly single, but sometimes in clusters of two or three together, rather conical, very hard, slightly incurved, pendulous, of a glossy light-brown colour, 6 in. long and 3½ in. broad near the base, which is uneven as well as the sides, the outer side being much the longest. *Scales* radiant, largest at the external base and down three parts of the outer side of the cone, deeply divided, much elevated, and prolonged into a blunt-pointed nipple, ½ an in. in length and ¾ of an in. broad; those nearest the base are bent backwards, the others being more or less convex, widest at the base, bluntly conical, slightly angular, and terminated by a blunt point; the scales on the inner side of the cone, and for four or five rows round the point, are very much smaller, quadrangular, and slightly elevated, with their points quite flat or slightly depressed (Gordon).

Distribution.—This beautiful Pine was first discovered by Coulter in Upper California, in lat. 36°, near the level of the sea, and almost close to the beach, where it was growing singly to the height of 100 ft. Hartweg also met with it on the descent towards the sea on the mountains of San Antonio, sixty leagues south of Monterey, where it formed a small wood extending along the beach, and where its deep grass-green foliage at that time of the year formed a marked contrast to the parched-up vegetation round about it. It was introduced into Britain in 1829.

Description.—This tree thrives best when growing singly, and within the influence of the sea, where it attains large dimensions, and is of an upright habit of growth. It much resembles the Remarkable Pine at first sight; but a closer inspection shows that its leaves are shorter and slenderer, while its cones are nearly three times as large, and have their scales much more raised. Its natural habit is to form a fine straight stem, clothed with branches down to the ground.

Economic Value.—The timber is tough and good, and suitable for boat-building. It is only of arboricultural interest here.

Soil and Situation.—It is quite hardy in our climate, and is accommodating with regard to soil, but thrives best on light and gravelly tracts and on inland situations considerably above the sea-level. It is said to be well adapted for planting near the sea; but in this respect it is little likely to prove superior to the Black Pines and the Pinaster for forming shelter-belts along the sea-coast.

Cultivation.—It is easily grown from the seed, like the Scots Pine.

(8) THE REMARKABLE PINE, *Pinus insignis* Douglas.

Specific Character.—*Leaves* divided into 3 needles in a sheath, deep grass-green, rather slender, usually straight, but often twisted in all directions, very densely set on the branches, of different lengths, from 4 to 6 in. long, ribbed on the inner sides, and sharp-pointed. *Sheaths* very short, smooth, and rather more than ¼ of an in. long. *Branches* numerous, rather irregular, and thickly set with slender branchlets at the extremities. *Cones* ovate-conical, much pointed, most developed on the exposed side, particularly towards the base or outer part, 3½ in. long and 2½ in. broad, mostly in clusters of from 3 to 5 round the stem or principal branches at the top of the tree, of a pale yellowish-brown when ripe, and with a smooth glossy surface. They point downwards, and remain for several years on the tree. *Seeds* middle-sized, nearly black, and with an ample wing, more than 1 in. long. It takes two years to mature its cones and seeds (Gordon).

Distribution.—This Pine is a native of various parts of California. It was introduced into Britain by Douglas in 1833.

Description.—In California this Pine attains a height of from 80 to 100 ft., with a stem of 2 to 4 ft. in diameter, whilst the branches are foliaged down to the ground. It is tolerably hardy, and makes very rapid growth. But it has a tendency to throw out autumnal shoots when planted on low-lying sites with rich soil, and it is then apt to get frost-bitten. When planted on dry soil, and in an elevated situation, this tendency is checked; its young wood ripens thoroughly, and does not get nipped.

This is a very graceful tree. It has irregular branches and a free habit of growth, while its grass-green foliage renders it a beautiful object in a park or on a lawn. The largest specimens reported to the Conifer Conference of 1891 had, in one case, a height of 90 ft. and a girth of 11 ft. at 5 ft. above the ground; and in another, a height of 68 ft. and a girth of 13 ft. The largest known tree in 1903 (52 years, in Co. Galway) is 90 ft. high and 14 ft. 3 in. in girth. In 1891 it was 74 ft. high and 10 ft. 8 in. in girth (Somerville).

Economic Value.—It is only of arboricultural interest in Britain.

Soil and Situation.—It should be planted on a light, dry loam, preferably poor rather than fertile, and in a situation where it can have plenty of light and air without being exposed to strong winds. It thrives better near the sea than in inland districts, and grows better in the west of Scotland than on the east coast.

Cultivation.—It is raised from seed in the usual way; but seedlings require the protection of a frame during the first winter, as they are apt to be injured by frost.

(9) SABINE'S PINE, *Pinus Sabiniana* Douglas.

Specific Character.—*Leaves* divided into 3 needles in each sheath, rather slender, from 10 to 12 in. long, glaucous-grey in every stage, twisted, and when fully grown bent downwards, and drooping during winter, sharp-pointed, angular on the inner side, but rounded on the outer side. *Sheaths* 1½ in. long, nearly entire at the top, with numerous rings, and wrinkled when old. *Branches* numerous, not very robust, covered with a violet bloom when young, and devoid of foliage, except near the extremities. *Cones* ovate, most developed on the outer side, particularly towards the base, pointing downwards, pressing against the stem, and remaining on the tree for a number of years, from 8 to 10 in. long and 6 in. wide, on footstalks 2½ in. long, and full of resin, particularly towards the base. *Scales* spatula-shaped, flat on the inner side, and rounded or slightly angular on the outer side, 2½ in. long, and 1½ in. broad on the larger bracts, but much less on the smaller scales towards the base, terminated by a strong, sharp, incurved hook, particularly on the exposed side and at the base, where some of the points are quite straight, and pointing upwards or towards the top of the tree. *Seeds* 1 in. long, oblong, tapering to the base, and flattened on the inside, hard-shelled, short-winged, and edible, and nearly double the size of those of the Large-coned Pine. *Seed-leaves* from 8 to 10 in number (Gordon).

Distribution.—This species is also a native of California, being found on the western Cordilleras of New Albion at a great elevation, and in woods on the heights at El Toro, a high mountain to the east of Monterey. It was introduced into Britain in 1832.

Description.—Sabine's Pine attains a height of from 100 to 150 ft., with a stem of 2 to 5 ft. in diameter. When growing isolated, it is furnished with branches down to the ground. It is never found in pure forests, but always intermixed with other trees. It is of a tapering habit, somewhat resembling Spruce and Silver Fir, and its long foliage gives it a very graceful appearance. The cones ripen in November. The climate of Britain, and more especially of Scotland, is hardly suitable for this species, as it demands a considerable degree of warmth before it can thrive. The largest specimen reported to the Conifer Conference of 1891 had a height of 24 ft. and a girth of $2\frac{1}{2}$ ft. at 5 ft. from the ground, and was growing at Pampisford in Cambridgeshire.

Economic Value.—The timber is white, but not durable. It is only of interest as an ornamental tree.

Soil and Situation.—Although tolerably hardy, it is not accommodating as to soil and situation. It thrives best in sheltered ravines and hollows, where the soil is deep and humose. It grows fairly well, however, on any light land that is neither too much exposed nor too elevated ; but its growth is then slow as compared with the rapid development in low-lying and sheltered hollows.

Cultivation.—It can be grown from seed in the same way as other Pines, but the seedlings require the protection of a frame during the first winter.

(10) JEFFREY'S PINE, *Pinus Jeffreyii* Murr.[1]

SYNONYMS—*Pinus Jeffreyana* van Houtté ; *P. deflexa* Torrey.

Specific Character.—*Leaves* divided into 3 needles, pendulous at the ends, deep-green, keeled on the inner face, rounded on the back, very acute pointed, and from 8 to 9 in. long ; *sheaths* persistent, $1\frac{1}{4}$ in. long when young, but very much shorter, lacerated at the ends, and of an ash-grey colour when old. *Buds* short, stout, imbricated, and resinous. *Branches* horizontal, a little declining, rather slender, and of a light yellowish-red colour. *Cones* large, ovate-conical, tapering most to the point, 8 in. long, and $3\frac{1}{2}$ in. in diameter at the widest part, which is near the base, and for the most part produced in clusters round the branches (Gordon).

Distribution.—This Pine was found by Jeffrey in the Shasta valley in Northern California, growing on poor sandy soil, and was introduced into Britain about 1852.

Description.—It is a handsome, hardy species, and a free grower. In California it attains a height of from 100 to 150 ft., with a stem of 2 to 4 ft. in diameter. The two largest specimens reported to the Conifer Conference of 1891 had respectively a height of 50 ft. and a girth of $3\frac{1}{2}$ ft. at 5 ft. from the ground, and a height of 48 ft. with a girth of $6\frac{3}{4}$ ft. They grew in Fife and Lincoln—both on the eastern side of Britain. No larger growth has since been formally recorded.

Economic Value.—The timber is coarse-grained and strong, being much like that of the Yellow Pine.

Soil and Situation.—It is an accommodating tree with respect to soil and situation. It grows fairly well on most soil, from light sands to stiff, clayey loams, and sometimes in situations that are a good deal exposed. A hardy and accommodating tree, it may perhaps prove profitable as well as ornamental.

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[1] This species is by some considered to be merely a variety of the Yellow Pine (*P. ponderosa*).

Cultivation.—The seed should be sown in good soil in a sheltered part, and seedlings protected under a frame during the first winter to prevent injury by frost. When one year old, they should be transplanted into the nursery-lines, where they should become sufficiently hardy to require no further protection. If plenty of seed is obtainable, however, such precaution will be unnecessary, as the loss of some of the yearling seedlings will not matter very much.

Continental Notes.—Experiments have long been made in the Prussian State forests with this as well as with the Yellow Pine. These show the Jeffrey Pine to be accommodating, for whilst sandy soil is found best suited to it, yet it can do fairly well even on heavy, binding land. In its sylvicultural character it resembles the Scots Pine, being like it a light-demanding species of tree. It is never likely to become so profitable a forest-tree as some of the other Californian Conifers.

(11) THE TUBERCULATED CONED PINE, *Pinus tuberculata* Gordon.

SYNONYMS—*Pinus californica* Hartweg ; *P. attenuata* Lemmon.

Specific Character.—*Leaves* divided into 3 needles in each sheath, thickly disposed on the branches, bright-green, rather stiff, broad, and flat, with an elevated rib running along their middle on the inner side, 4½ to 5 in. in length. *Sheaths* short, smooth, and not more than ½ an in. long on the young leaves, but much shorter on the older ones, and only partially persistent. *Branches* not very stout, rather numerous and irregular, with a roughish bark. *Buds* below the middle size, imbricated, and not very resinous or pointed. *Cones* mostly in clusters of four, but sometimes solitary or in pairs, and only produced on the main stems, of a long, conical shape, nearly 5 in. in length, and from 2 in. in breadth, the outer surface curved, the inner straight, widest near the base, and gradually tapering to the point, quite sessile, and uneven-sided at the base, very hard, of a light-brown colour, or silvery-grey when old, very glossy, and full of resinous matter: they stand off at nearly right angles when old, although rather pendulous when young, and remain on the trees for years without even opening or shedding their seeds (Gordon).

Distribution.—This tree was first discovered by Coulter to the south of Monterey, where it was intermixed with other Pines, and especially with the Radiated Cone Pine, almost close to the beach. Hartweg also found it growing inland on the Santa Cruz Mountains, sixty miles to the north of Monterey. It was introduced into Britain about the year 1847.

Description.—It is a tree of slow growth, seldom attaining over 40 ft. in height, and only about 10 to 12 in. in diameter. While young, it is prettily clothed with green foliage ; but old trees assume a gnarled and deformed appearance. At a very early age it begins to bear cones, which are at first produced only on the main stem, and are persistent for a long time. Jeffrey found trees with as many as 20 whorls of cones on the trunk—the growth of as many years ; and the branches were also covered with cones in the same way as the trunk. As the tree grows older, the stem and branches get covered with these cones, remaining persistent until they rot away, which gives a very peculiar appearance to the mature tree. It is quite hardy in Britain.

Economic Value.—The timber is red and hard ; but as the rate of growth is slow, the tree has no sylvicultural value in Britain.

Soil and Situation.—Here this tree thrives best on a light, deep, dry loam, and on rather low-lying, sheltered situations.

Cultivation.—The details already given as to the Jeffrey Pine also apply to this species.

III. QUINATE PINES, HAVING USUALLY FIVE NEEDLES IN EACH LEAF-SHEATH.

(1) THE WEYMOUTH or WHITE PINE, *Pinus Strobus* L.

SYNONYM—*Pinus canadensis quinquefolia* Duham.

Specific Character.—*Leaf* in each sheath divided into 5 needles, very slender, 3 to 4 in. long, 3-sided, soft, and of a light-glaucous or bluish-green colour, marked when young with silvery channels on one side. *Sheaths* very short, almost wanting, and soon falling off. *Branches* short, in whorls, thinly clothed with foliage, and having a smooth shining bark. *Cones* long, narrow, lax, slightly curved, cylindrical, tapering to rather a sharp point, and pendulous, from 5 to 6 in. long and from $1\frac{1}{4}$ to $1\frac{1}{2}$ in. broad, with a footstalk $\frac{3}{4}$ in. long. *Seeds* small, ovate, of a dull-grey colour, and with the wing 1 in. long (Gordon).

Distribution.—The Weymouth Pine, or "**White Pine**," is indigenous throughout Canada and all the Northern American States. It is abundant in most parts of Canada, and especially in the valleys of the rivers Ottawa, Madawaska, and Gateneau, where large quantities of it are felled every year and floated down the St Lawrence for shipment to Europe. It is most abundant between 43° and 47° north latitude, from the east of the Mississippi and the Alleghany Mountains northwards to the Gulf of St John and Lake Winnipeg. It was introduced into Britain in 1705, and was extensively planted first of all on Lord Weymouth's estate in Wiltshire, whence it derives its common European name.

Description.—It is a very hardy species, and even in Livland and Kurland can endure the severe winters and the hot short summers of the far north of Europe, when planted out in parks as an ornamental tree. Throughout Canada and New Hampshire it grows to large dimensions, the stems averaging about 150 ft. in height and from 2 to 3 ft. in diameter, although many are upwards of 200 ft. in height, and have stems of from 5 to 7 ft. in diameter, which show from 350 to 425 annual rings.

Pure natural forests of this Pine are seldom found on sandy soil, but generally on gravelly ridges and knolls. On dry land of more fertile description it usually forms mixed woods, in association with Beech, Lime, Maple, and other broad-leaved trees. And it is invariably in such mixed woods that trees of the largest size are to be seen. It has a very strong tendency to straight, upright growth, and has generally a stem free from branches for at least two-thirds of its height. Its branches are never of large dimensions, nor do they reach far out from the stem. Even in trees about 200 ft. high, the branches seldom extend more than 20 ft. on either side, and are always arranged in regular whorls, with clear spaces between, formed by the long leading-shoots. On young trees the bark is smooth; and the leaves are longer than on old trees, in general appearance having close resemblance to those of the Nepaul or Lofty Pine. As the tree ages, however, the bark becomes rough and even rugged, and of an ash-grey colour; but it never scales off in flakes like the bark of many other Pines. Like the Scots Pine, the Weymouth retains its foliage for two to three years, according to the quality of the soil and situation.

When growing singly, the Weymouth Pine is a handsome tree; and it is far more as an ornamental tree than for timber production that it deserves attention in this country. In favourable situations it rapidly attains very fair dimensions as a park tree, especially in the warmer tracts of Central and Southern England, and a windfall tree in Tortworth Park (Gloucestershire) was found to contain nearly 300 cubic ft. of timber. Even in Scotland it reaches a height of 60 to 70 ft., and may contain upwards of 40 ft. of timber when little over forty years of age.

The two largest specimens reported to the Conifer Conference of 1891 were growing in Perthshire. The largest (at Logie, near Scone) was then 90 ft. in height and $7\frac{1}{2}$ ft. in girth at 5 ft. above the ground. Later authenticated records are not obtainable.

Economic Value.—Under the name of "White Pine" this timber is more used in America than any other Pine-wood; and it is also, under the trade name of "Yellow Pine," our largest coniferous import from America, being very largely used for housebuilding and other constructive purposes.[1] Being fine-grained, close, and not liable to warp, it is very suitable for interior work in finishing off buildings. It is the best coniferous wood imported in bulk for joinery and common cabinetmaking, though it is softer, less durable, and less able to resist insect attacks and dry-rot than the better qualities of "Red Pine" (Scots Pine) from the Baltic. The accounts as to the quality of the timber grown here vary greatly, no doubt according to the soil and situation on which it is produced. Some find it rather soft and not durable; while others extol it as a capital wood, even for outdoor work. In some parts of Co. Wicklow it is said to be of first-rate quality.

The wood of the Weymouth Pine is light and soft, and its mean sp. gr. of 0·33 when green and 0·39 after seasoning shows it to be one of the lightest of Conifers. It is soft in texture and even in grain, and can be worked and planed easily; and as it only shrinks from 2 to 3 per cent, it is well adapted for flooring, or for veneered furniture. But durability is not its strongest

[1] The White Pine is by far the most valuable of Canadian trees, and notwithstanding the reckless waste that characterised lumbering operations until very recently, there still remains in Canada an immense quantity of growing timber from which vast quantities of lumber will be made. . . . White Pine is exported principally in the form of square timber, deals and boards. Its chief uses are in construction work of all kinds, and as the slabs and edgings are made into shingles and laths there is now little waste of material. The wood is light, soft, and not strong, but it is suited for a great variety of purposes, as it is easily worked and free from resin (Macaun, *The Forest Wealth of Canada*, 1902, p. 32).

In 1883 the Forestry Association of Quebec memorialised the Governor-General of Canada to introduce forest conservation, chiefly with regard to White Pine. The result has been disappointing :—

"With regard to this memorial, I have to say that I am yet ignorant of any serious consideration having been given to it by the Government of the time, or of any rational attempt having been made by any succeeding Government, to ascertain the true condition of our forests of **White Pine**, which is the chief factor in our great Canadian timber trade, though from what information I have on the subject I am forced to believe that, if the existing indifference continues for a few years more, the inquiry, in so far as regards our White Pine forests, may be answered in as few words as the schoolboy's essay on the snakes in Ireland, which said, 'There are no snakes in Ireland,' for there will be no **White Pine** forests in Canada" (*Canadian Forestry Association, Fourth Annual Report*, 1903, p. 10).

point, for it is often ranked with Aspen, Lime, Poplar, and Willow as the least durable of the forest-trees now cultivated in Europe. Like these, however, it should be well suited for the manufacture of packing-cases, or of cellulose for paper.

Soil and Situation.—To thrive well in Britain it requires a good, deep, dry, and light loam, and a somewhat sheltered situation. Its deep-reaching tap-root needs a deep soil, otherwise the tree is liable to attacks of insects and fungi. It often does well among other trees on dry sloping banks, where it has room to spread its branches a little, but is still sheltered from wind. Continental experience has shown that, though it grows well on sandy soil resting on a moist subsoil, yet it thrives best on loamy and clayey land; even when this is of a marshy description, it can often be rendered dry by the strong transpiration of water from the foliage of pure woods of this tree. A very dry soil is unsuitable for it. It is rather a tree of the lowlands and of sheltered valleys than of exposed hilly or mountainous tracks.

Cultivation. — It is raised from seed, which generally ripens in this country about the end of October, and should be collected at once in order to prevent it being scattered in November. The cones are easily opened and the seeds extracted by exposure to the sun. When the seed has been taken from the cones during winter, it should be sown about the beginning of April, and the seedlings treated like those of the Scots Pine.

Continental Notes.—For over sixty years this species of Pine has received sylvicultural attention in the German State forests, so that more is known there of its characteristics when grown in Europe than of those of most of the other American Conifers.

It grows more quickly than Scots Pine when young, and forms woods containing a larger number of stems per acre, because, without being exactly a shade-bearing species of tree, it can thrive with less intensity of light than the Scots or even the Black Pines. After attaining twenty to thirty years of age, however, it makes only a slightly increased demand for individual growing space and ramification than is necessary for the thriving of Spruce and Silver Fir as woodland crops.

In rapidity of growth and quantity of timber produced, it excels the European Conifers; and through its great transpiratory power and the rich fall of soft, easily decomposable needles, it soon improves inferior soil of rather a moist description. It is a hardy species, well suited for filling up blanks in plantations on low-lying localities exposed to late frosts, where the side-shade cast by the rest of the crop might prove too much for Larch and Scots Pine. It is said to have been found useful for planting on poor limy soil, and to do fairly well on western exposures that can no longer bear fair crops of Beech or even Spruce. It grows quickly from its third year onwards, and soon outgrows weeds. As to its density of crop and its productive capacity, Burckhardt (*Säen und Pflanzen*, 1893, p. 455) says that—

> Along with rapid development the Weymouth Pine combines a remarkable density of crop, maintained till its maturity, and differing entirely from the natural habit of growth of the Common Pine and the Larch, which thin themselves with advancing age,

often to a very serious extent. In this respect the Weymouth Pine has much in common with Spruce and Silver Fir. Crops raised by planting are often so very crowded as to hinder the natural selection and development of the dominant stems, so that they need to be heavily thinned.

Woods cleared at about 60 to 70 years of age yield a large quantity of timber. Even pole-thickets and young highwoods give a large return in timber. The mean annual increment produced by 30- to 50-year-old crops, growing in close canopy on loamy, sandy and marshy soil of only average quality, we have found to amount to 137 cubic ft. per acre per annum—or including the returns of previous thinnings, 178 cubic ft. per acre per annum. From other sources the quantity of timber in a 70-year-old crop is estimated at nearly 14,400 cubic ft. per acre. All crops will not yield such good returns, especially when covering extensive areas; yet the fact remains that this species produces a large quantity of timber. But so long as we cannot be sure of disposing of the wood, its mere rate of production will not lead to extensive plantations being formed of it. More might certainly, however, be done than has hitherto been the case in order to provide stores of material for the supply of the coming future demands for timber.

Even if planted out in blanks in young Scots Pine woods, it catches the latter up within six or eight years, and then begins to suppress that more valuable species. For the formation of plantations of Weymouth Pine, yearling seedlings or two-year-old plants are put out naked (notching). Planting should be closer than with the Common Pine. In Germany the Weymouth Pine is usually planted at 3 ft. by 3 ft. on inferior dry soil, or at 4 ft. by 4 ft. on land of better quality.

(2) CEMBRAN, SIBERIAN, or SWISS STONE PINE, *Pinus Cembra* L.

SYNONYMS—*Pinus montana* Lamk.; *P. mandschurica* Regel.

Specific Character.—*Leaves* divided into 5 needles, from 2 to 3 in. long, sharp-pointed, 3-ribbed, one of the ribs green and shining, and the other two white. *Sheaths* deciduous. *Buds* broad, globose, with a long narrow point, whitish, without resin, and mostly solitary at the end of the shoot. *Cones* about 3 in. long and 2½ in. broad, ovate, erect, and of a violet colour. *Seeds* very large, wingless, and edible (Gordon).

Distribution.—The Cembran Pine is indigenous to Siberia, Tartary, Hungary, Austria, Switzerland, Italy, and parts of France. It is sometimes found on the Swiss mountains at a greater height than any other Conifer. It was introduced into Britain in 1746. It is in reality far more of an Asiatic than a European tree, for it is chiefly distributed throughout Central Asia. In comparison with that, the tracts where it is indigenous in the Alps and Carpathians are mere small outlying patches, away from the main area of distribution.

Description.—This is perhaps the hardiest of all the Pines introduced into Britain. It is easily distinguished by its erect habit of growth, by the shortness of its annual shoots, even under favourable circumstances seldom exceeding 12 in., and by its branches being regularly disposed in whorls from the bottom to the top of the stem. It is of slow growth, and even when young seldom grows more than 10 in. in any one year. It is not a timber-tree, and it cannot even be called ornamental. Its peculiarity is its chief claim to the attention of arboriculturists. If planted among trees of a more rapid growth, it gets completely suppressed in a few years. When of spontaneous growth at the higher elevations in its Alpine home it takes nearly seventy years to attain a height of 6 ft.; even when grown artificially, in its quickest time of development from the tenth to the thirtieth year, it only increases by less than 9 ft. in height there on the average. Regular whorls are only formed by it there from the sixth to the thirtieth year, and its total height seldom exceeds 70 ft., whilst its stem varies from 3 to 5 ft. in diameter. Such trees are often from 500 to 700 years old. The two largest specimens reported to the Conifer Conference of 1891 were respectively 68½ ft. high by 5 ft. in girth at 5 ft. above the ground, and 45 ft. high by 9 ft. in girth; they were growing in Kent and Northumberland.

Economic Value.—Of course in this country it will never be grown for the sake of its timber; but it is said to be of fair quality, though rather soft, and much used on the Continent for wainscoting and joinery. The wood is of a light-brown colour when mature, and is known throughout Russia as "**Siberian Cedar.**" In the countries where this tree abounds, the seeds form an article of diet, and many of the poorer classes in Eastern Russia often have little else than these "**Cedar-nuts**" for their winter's food.

Soil and Situation.—It is accommodating as to soil and situation, and will grow in most places where Scots Pine thrives. But to attain a good size, and to develop quickly, it should be planted on a good, deep, rather light and dry soil, and in a situation not too elevated or exposed.

Cultivation.—The seeds should be sown as soon as gathered, else they are apt to lie dormant till the year following that in which they are sown. When they have become dry by keeping, the best way is to cover them with damp sand, and allow them to remain over summer; then sow them during the following spring, not later than March. The large seeds should be sown thinly, and covered with about three-quarters of an inch of fine earth. The plants are easily grown, and are easy to transplant, as the roots are always well-fibred. They should have two summers' growth in the seed-bed before removal into the nursery-lines, as even then they will be small compared with other Pines. After standing for two years in the nursery-rows, they may be planted out, though even then (at four years old) they will generally not be over 1 ft. high.

Continental Notes.—Its spontaneous growth in very exposed Alpine localities near the perpetual snow and the glaciers shows that it is very hardy. Its natural requirements are a short but very warm summer, and a soil that is constantly fresh or moist, but not binding: given these conditions, its best development is attained on somewhat argillaceous, loamy, or limy soil. In the higher Alpine tracts seed-production does not begin till about sixty years of age; but in our milder climate it often begins at about twenty-five years, and even earlier.

In the Engadine, Cembran Pine seed is sown in strong boxes of larch-wood covered with wire-netting to protect it from voles and birds. These boxes are about 8 ft. long by 3 or 3½ ft. broad and 2 ft. deep, and are divided in half by a board placed in the middle to give support to the wire-netting above. They are let into the ground, and then filled up with good soil, on which the seed is sown. A box of this sort can contain from 10,000 to 12,000 seedlings when the seed is thickly sown.

(3) THE NEPAUL or LOFTY PINE, *Pinus excelsa* Wallich.

SYNONYMS—*Pinus Strobus* Hamilt.; *P. Strobus excelsa* Loud.; *P. Nepalensis* Pinet. Woburn.; *P. Dicksoniana* Hort.; *P. Peuke* Griseb.?

Specific Character.—*Leaves* divided into 5 needles, very long, three-edged, very glaucous on the inner faces, bluish-green, and rounded on the outer one, from 6 to 8 in. long, very slender, and mostly drooping. *Sheaths* short at first, but soon rolling up, and finally falling off. *Branches* in regular whorls, and spreading; those near the bottom reflected, while the upper ones are more or less ascending; branchlets slender, long, and spreading; *male flowers* in dense clusters. *Cones* solitary, or sometimes two or three together round the leading-shoots, of a cylindrical or somewhat conical shape, from 6 to 9 in. long, and about 2 in. broad near the base, tapering towards the point, and with a footstalk nearly 1 in. long; when young of a pea-green colour, and somewhat erect, but when fully grown completely pendulous, and of a pale-brown colour, full of resinous matter in the shape of transparent drops (Gordon).

Distribution.—This species is found plentifully along the central range of the Himalayas, from Kafiristan eastwards to Bhutan and Nepaul, at elevations of from 5000 to 10,000 ft. It attains a height of 100 to 150 ft. It was introduced into Britain in 1823. In the Kamaun district of North-western India it forms extensive forests in association with the Deodar. But it is also indigenous to Europe, if it be identical with the *P. Peuke* which Grisebach found on Mount Peristeri in Macedonia, Pancic on the Koru in Montenegro, and v. Janka on the Perimdagh in the Balkan range: recent evidence, however, goes to show that, though closely allied, it is not quite identical with that species. In these European habitats it is found at 5000 to 6000 ft. above sea-level as a low tree, although near its upper limit it is merely a bushy shrub.

Description.—It closely resembles the Weymouth Pine, but is readily distinguishable by its much longer leaves and thicker cones. It is a tree of open growth, with spreading branches, and a somewhat conical outline. It is ornamental, and is perfectly hardy. It is of rapid growth, but does not thrive when exposed to high winds. In moderately sheltered parts of the country, however, it grows well, rapidly attains a good height, and is not affected by frost. It grows best when planted in large patches, either by itself or else mixed with Larch, up to nearly 1000 ft. above sea-level. The tallest specimen reported to the Conifer Conference of 1891 had a height of 70 ft. and a girth of 6 ft. at 5 ft. above ground; while the largest stem had a girth of 16 ft. and a height of 44 ft. The largest tree officially reported in 1903 (74 years, in Bucks) was 90 ft. high, and 8 ft. 2 in. in girth (Somerville).

Economic Value.—The timber is soft and white, but compact and resinous. It can only have an arboricultural interest in Britain.

Soil and Situation.—It is accommodating as to soil and situation, and grows well on most kinds of soil, and in exposed as well as sheltered situations. It does best, however, on a light, dry, deep soil, and in a moderately-sheltered situation. It needs plenty of growing-space, and does not stand being crowded among other trees.

Cultivation.—The seeds should be sown on light, well-prepared soil, and the seedlings treated like those of the Scots Pine. The plants are easy of cultivation, and when the yearling seedlings have been transplanted into the nursery-rows they soon become large enough for planting out.

(4) LAMBERT'S GIANT-CONED PINE, *Pinus Lambertiana* Douglas.

Specific Character.—*Leaves* divided into 5 needles, 4½ in. long, rather stiff, of a dull but not shining green colour, rather rough at the edges, and slightly glaucous when young. *Sheaths* very short, or nearly wanting on the old leaves. *Branches* in whorls, numerous, rather pendulous towards the extremities, and densely clothed with foliage. *Cones* very large, from 12 to 16 in. long, and about 4 in. in diameter, deep-brown, cylindrical, tapering to the point, mostly straight, and destitute of resinous matter, pendulous when full grown, although nearly erect when young. *Seeds* large, oval, ⅞ of an inch long, and with the wing 1¾ in. long, and dark-brown. They require two years to ripen, are pleasant to the taste, and are used for food by the North American Indians (Gordon).

Distribution.—The Pine is also called the "**Sugar Pine**," and is indigenous to the northern parts of California and of North-west America between 35° and 45° of latitude. It nowhere forms pure forests, but is frequently found intermixed with other Pines and Firs, generally about a hundred miles inland. It attains its largest dimensions on a sandy soil. It was introduced into Britain by Douglas in 1827.

Description.—The Lambert Pine attains a height of 100 to 200, and even according to some accounts 300 ft., with a stem of 7 to 15 ft. in diameter near the ground. It has an open pyramidal crown of branches spreading out over a clean bole of about 100 ft. The specimens grown in this country are open-crowned, and with widespreading branches, but have nothing very remarkable about them. It is hardy, and does not seem liable to be injured by frost or rapid change of climate. The largest specimens reported to the Conifer Conference of 1891 had respectively a height of 50 ft., with a girth of 6⅔ ft. at 5 ft. above the ground, and 45 ft., with a girth of 9 ft. The former is now (1903, at 55 years old) 57 ft. high, and 7½ ft. in girth. In 1903 the largest known tree (60 years, in Bucks) was 82 ft. high, and 9 ft. 5 in. in girth (Somerville).

Like the seeds of Sabine's Pine and the Stone Pines, those of the huge 12- to 16-in. cones (whence the name "**Giant-coned Pine**") of this species are edible. The resin exuded from this tree is sweet, and forms the well-known "**chewing-gum.**"

Economic Value.—The timber is white and soft. About thirty years ago it was strongly recommended for cultivation on an extensive scale in the State forests of Northern Germany in admixture with Larch and Spruce; but many other species of Conifers (such as Douglas Fir, Menzies Spruce, and the Black Pines) where held to be far more deserving of attention.

Soil and Situation.—The Lambert or Giant Pine does not appear to be very particular with respect to soil, as good specimens of it may be seen growing on poor gravelly land, on a light peaty soil, on light as well as on heavy loam, or even on argillaceous soil. If the land on which it is planted be dry, and the subsoil open and permeable, it will succeed on a great variety of soil, and find conditions for its normal thriving; but it seems, on the whole, to do best on a light loam, rather of a poor than a rich description, and on situations freely exposed to light and air—for, like most Pines, it is a light-demanding species of tree.

Cultivation.—The seed of this Pine may be sown on any well-prepared piece of ground in the usual way, as it vegetates freely; and the young plants, being hardy, require no protection whatever.

(5) THE MONTEZUMA or MEXICAN PINE, *Pinus Montezumæ* Lamb.

SYNONYMS—*Pinus occidentalis* Humboldt; *P. Russelliana* Lindl.

Specific Character.—*Leaves* divided into 5 needles, from 3 to 4 in. in length on the wild specimens, but on young plants from 4 to 5 in. long, rather stout, rigid, 3-edged, and rough at the angles, thickly set on the young branches, and supported by long, sharp-pointed, brown scales at the base of each sheath, of a dark-green on the upper surface, and slightly glaucous on the under side on the young leaves, but on old full-grown leaves dark-green on both sides. *Sheaths* persistent, or not falling off, nearly ½ an in. in length, and rather rough or jagged on the ends. *Seed-leaves* on the young plants from 6 to 8 in number. *Branches* few, very irregular, rather stout, and twisted. *Bark* very rough, particularly on the young wood, which is covered with numerous long, broad, sharp-pointed scales. *Buds* few, imbricated, non-resinous, and rather lengthened. *Cones* in clusters of three or four together, but frequently single, nearly horizontal, from 4 to 6 in. in length, and 1¾ in. broad at the widest part, which is near the middle, then tapering to both ends, and slightly incurved, but especially towards the point, which is rather small (Gordon).

Distribution.—The Montezuma Pine is plentiful in the mountainous districts throughout many parts of Mexico. Hartweg found it on the mountains of Mexico, near Ajusco, forming a tree 40 ft. high. It occurs also on the mountains of Orizaba, at an elevation of about 10,000 to 11,000 ft., where it grows to a height of 40 to 60 ft. It was introduced into Britain in 1826.

Description.—It does not grow to any great size, and is merely a broad-spreading, thinly-branched, and rough-barked Pine, only worthy of being cultivated as a variety in a pinetum. But with its long needles, sometimes in young trees attaining a length of 8 to 12 in., it is undoubtedly a very beautiful ornamental species for arboricultural purposes and landscape-gardening.

Economic Value.—In Mexico the timber is very resinous and of excellent quality; but in Britain the Scots Pine and many other Conifers are much superior to it. It therefore possesses no claim to sylvicultural attention.

Soil and Situation.—Although, in a general way, it is hardy in this country, still it is not accommodating as to soil and situation. It seems to require a good, light, loamy soil, and as sheltered and favourable a situation as can be allotted to it.

Cultivation.—Young plants need to be protected by a frame during the first and also often during the second winter, until they have succeeded in forming good hard wood, and have become less sensitive to the effects of cold.

(6) THE FIVE-LEAVED MOUNTAIN PINE, *Pinus monticola* Douglas.

SYNONYM—*Pinus Lambertiana brevifolia* Hort.

Specific Character.—*Leaves* divided into 5 needles in a sheath, short, smooth, and blunt-pointed, from 3 to 4 in. long, rather 3-sided, slender, glaucous-green, and with a silvery appearance when young. *Sheaths* short and imbricated. *Cones* long, cylindrical, 7 in. long and $1\frac{3}{4}$ in. wide, tapering to rather a blunt point, smooth, and full of resin, generally in whorls, and on short footstalks. *Branches* rather stout, short, and densely clothed with foliage (Gordon).

Distribution.—This Pine is indigenous to Northern California, where it is abundant on poor granitic soil at an elevation of about 7000 ft. (Trinity Mountain). It is also met with on the still higher mountains at the Grand Rapids of the Columbia, and on the rocky banks of the Spoken River. It was introduced into Britain in 1831.

Description.—It is a handsome tree, well clothed with foliage, and whose branches present an irregular outline. It grows to a large size in America, and even here has proved of rapid growth. The largest specimen reported to the Conifer Conference of 1891 was a tree at Scone measuring $71\frac{1}{2}$ ft. in height, and having a girth of 5 ft. 11 in. at 5 ft. above the ground; and this tree is now (1903, at 51 years old) 83 ft. high, and 7 ft. 1 in. in girth.

Economic Value.—The timber is white, fine-grained, and tough; but it is merely an ornamental tree here, and unfortunately it is very liable to a fungous disease (*Cenangium abietis*), which has recently proved fatal to it in many districts.

Soil and Situation.—It thrives on most kinds of land, and appears to be of an accommodating nature. In Britain it does well on light and gravelly soil, and on land of quite an opposite character. It seems a hardy tree, possessing considerable power of accommodating itself to a great variety of soil, provided it is deep, porous, and dry. It stands well in an open airy situation, but can hardly be said to thrive in wind-swept positions.

Cultivation.—When seed is sown on the open ground in the usual way, the seedlings come up perfectly well, but they are usually protected in a frame during the first winter—though more from a fear of losing any of them than from the young plants being really sensitive.

(7) HARTWEG'S PINE, *Pinus Hartwegii* Lindley.

Specific Character.—*Leaves* generally divided into five needles, though frequently only in fours, very dense, 6 in. long, rather slender, curved, and of a dark-green colour. *Sheaths* long on the young leaves, but with a shrivelled appearance on the old ones, and jagged at the ends. *Branches* few, very robust, and irregularly placed on the stem.

Cones growing in clusters, pendulous, 4 to 5 in. long, and nearly 2 in. broad, oblong, tapering to the point, which is rather blunt, incurved, and of a dark-brown colour (Gordon).

Distribution.—This species was found by Hartweg on the Campanario Mountain in Mexico, at an elevation of 9000 ft., where its lower limit begins when the upper limit of the *Picea religiosa* is reached. It is also found growing to a height of about 100 ft. on the mountains of Orizaba, and near the Real del Monte, at an elevation of nearly 10,000 ft. It was introduced into Britain in 1839.

Description.—This is a handsome Pine, which attains a height of over 50 ft., and has a dense, compact crown of beautiful dark-green foliage. It is a very robust tree, with stout branches, which form a striking feature in its general habit of growth; and it is readily distinguishable from most other Pines by the very strong appearance of its shoots, to which its long slender leaves give a peculiar effect. It is hardy enough for favourable localities in Britain. The largest specimen reported to the Conifer Conference of 1891 was one on the Mountstuart estate, in Bute, which measured 33 ft. in height and 1 ft. 10 in. in girth at 5 ft. above the ground.

Economic Value.—In its native climate its wood is said to be very resinous and durable. But here it is only of arboricultural interest.

Soil and Situation.—This species of Pine does best on rather a poor and light loam, and in the free exposure to light and air required by a light-demanding tree. If planted on rich soil, its young shoots do not mature, and are therefore liable to be injured by frost.

Cultivation.—Although hardy enough for the milder parts of England, still the plants are somewhat sensitive and tender when young: they should therefore be protected by a frame for the first two winters.

2. SPRUCE, *Picea* Link. (LINNÆAN SYSTEM, MONŒCIA MONADELPHIA).

SYNONYMS—*Abies* DC.; *Abies* Loud.

Generic Character.[1]—The leading characteristics of the Spruce Firs are: the projecting cushions at the base of the *leaves*, which give a rough, pegged appearance to the shoots; the four-sided leaves (flat in the section *Omorica*), uniform in structure; the usually pendulous woody *cones*, ripening in the first year, and the *scales* of which do not fall away one from the other, as in the Silver Firs. *Bracts* concealed, not projecting, free from the scales except at the base. Stamens in spike-like masses. *Anthers* 2-lobed, apiculate. *Pollen-cells* winged. *Seeds* small. *Seed-wings* obovate, separable, covering the upper side of the seed. *Cotyledons* 8-10, 3-sided, toothed, primary leaves flat, denticulate (Masters).

The Spruces or Spruce Firs are all evergreen trees, indigenous to Europe, Asia, and America, and remarkable for their tall, erect, pyramidal forms and dense foliage. In Britain they flower in May and June, and their cones ripen in the spring of the following year. All bear seed at a very early age, and all may be readily propagated by cuttings taken in spring or autumn; and throughout Britain this is a general practice for some of the rare species. It is a genus possessing great sylvicultural and aboricultural value. Spruces are easily distinguished from Pines by their tall pyramidal form, their more rapid growth, and their comparatively slender branches, which seldom grow very thick, but gradually die off under the shadow of the dense crown of foliage as the trees grow old. But still more characteristic is the disposition of their leaves on the branches. In the Pines the leaves of the short shoots are divided into two or more needles in each

[1] Willkomm makes two sections—I. *Eupicea*, with four-sided leaves; and II. *Omorica*, with flattish leaves with stomata, and with white bands on the upper surface.

sheath ; whilst in the Spruces the leaves or needles grow singly, and are scattered chiefly along the upper sides of the branches. During the late summer from 3 to 5 buds are developed along with and immediately under the terminal bud, and these form a whorl in the following spring. These side-shoots do not again bud in whorls ; but 2 or 3 buds generally form near their ends, and in developing give the extremities of the twigs a 3-pronged, fork-like appearance. As the foliage is persistent for five to seven years, the Spruces are naturally capable of bearing a considerable degree of shade ; hence they remain long in close canopy, and in their strong upward growth form straight long stems that clear themselves thoroughly of branches. When growing in isolated positions, they retain a dense mantle of foliage down to the very ground, and assume a conical outline.

(1) THE SPRUCE, SPRUCE FIR, or NORWAY SPRUCE, *Picea excelsa* Link.

SYNONYMS—*Pinus Abies* L.; *P. Picea* Du Roi; *P. excelsa* Lamk.; *Abies Picea* Mill.; *Abies excelsa* DC. and Loud.; *Picea vulgaris* Link.

Specific Character.—*Leaves* scattered, solitary, 4-sided, deep sombre green, curved, stiff, sharp-pointed, more crowded together laterally than on the upper and under sides, and nearly 1 in. long. *Branches* on young trees nearly horizontal, and disposed in regular whorls from the base to the summit ; but on old trees the bottom branches drop off, and the others become rather pendulous. *Cones* produced on the points of the upper branches, and when full grown becoming pendent; they are from 5 to 7 in. long, and $1\frac{1}{2}$ to 2 in. in breadth. *Seeds* very small, with a wing $\frac{3}{4}$ in. long. *Seed-leaves* from 7 to 9 in number (Gordon).

Distribution.—The Common or Norway Spruce is indigenous to the hills and mountains of Europe and Asia, in places where the soil is moist and the atmosphere cold and humid. It is, however, commonest in Norway, Sweden, Lapland, Denmark, and Northern Germany, though also found in some of the mountainous districts of France, the Alps, the Pyrenees, and Switzerland. It was introduced into Britain about 1548 ; but fossil remains in the Norfolk clays prove that it formerly grew in England during the later Tertiary period.

No other European Conifer has such a wide distribution throughout Europe as the Spruce ; and, indeed, among forest-trees altogether, it is probably only surpassed in general distribution by Aspen, Scots Pine, Rowan, and perhaps also Birch. Its northern limit begins on the west coast of Norway at 67°, sinks to 65° in Sweden, and then ascends to $69\frac{1}{2}$° in Finland, where it reaches its polar limit, which thence trends in a south-easterly direction across Russia. Its eastern limit is not determinable, as it gradually merges into the Siberian variety (*Picea obovata*) having smaller and thinner foliage, and conical cones only about half as long as those of the Common Spruce. In general, however, longitude $55\frac{1}{2}$° may be taken as about its eastern limit. In South-eastern Europe its southern limit is in Servia about 43° latitude, whence it trends westwards in a curve across Northern Italy and above Nice, thence following the southern boundary of the Cevennes, and stretching across the Pyrenees down to below the Maladetta Mountains, where its lowest equatorial limit is reached. From there it returns at an acute angle into the mountainous regions of France (Willkomm).

The Spruce is essentially a tree of the mountains, and not of the plains or the lower hills ; but the height to which it ascends the mountain-slopes varies, of course, enormously with the geographical position of any particular point. Thus in Norway at 67°, where the snow-line begins at 3600 ft., it does not ascend to higher altitudes than 2700 to 2900 ft. ; whilst in the Central Pyrenees it occurs at 4000 to 5000 ft., and is to be found in the Upper Engadine at an elevation of 6500 ft. above the sea-level.

Observations in various parts of Europe have shown that in order to commence active vegetation in spring a mean cumulative warmth of 372° C. (or 670° Fahr.) is requisite, and that the Spruce will only thrive in localities where the sun is above the horizon for at least 14 hours at the precise time at which this total of warmth is reached in spring. Thus, near Vienna this degree of warmth is reached when the day is only 13 hours 54 minutes in duration, and there the Spruce will not thrive; but at Kaltenleutgeben, at an elevation of over 1000 ft., that total amount of warmth is reached only two days later, when the day is actually of 14 hours' duration, and there the Spruce finds the essential condition for its thriving fulfilled (Willkomm). This seems worthy of note as being a natural law affecting the artificial distribution of Spruce for forming woodlands to be worked for profit.

Description.—The Spruce is one of the tallest of the European Coniferæ. Where indigenous, it frequently attains a height of 150 to 160 ft., with stems of 4 to 5 ft. in diameter; and even in Britain it is not unusual to find specimens above 100 ft. in height, with stems 2 to 3 ft. in diameter. When growing in the open, the stem rises perpendicularly and is clothed with a conical mantle of slender branches. When the tree stands free and alone, these branches gradually become smaller and shorter as they are found higher up the stem, thus giving the tree a very regular conical outline. In the younger stages of growth the slender branches generally stretch out horizontally, but in old trees they droop a good deal, and this pendulous habit gives them a very graceful appearance. When planted along with quicker-growing trees, like Larch, it forms good shelter and cover for game. As a hedge-plant it stands cutting well, and makes a fine ornamental evergreen hedge in gardens. The largest Spruce reported at the Conifer Conference, 1891, was 132 ft. high and 12½ ft. in girth (Studley Royal, near Ripon).

Economic Value.—Spruce timber is, next to that of the Scots Pine, perhaps the most useful for boards, planks, and roof-scantlings. It is very light and pliable when mature. Our imports of Spruce timber from the Baltic and Norway coasts, under the trade names of the "White-wood," "White Fir," or "White deal," rank next in importance to that of Scots Pine for building purposes, as well as scaffolding, pit-wood, &c. In Britain the quality of the wood is, however, like that of the Common Pine, greatly influenced by the soil and situation. When grown on a thin dry soil, the wood is brittle and short-grained; but when raised upon deep loam, resting on a cool subsoil, it is of much better quality. In its younger stages of growth Spruce yields a more durable timber than Scots Pine of the same age; but the reverse is the case when the trees are fully mature. To produce timber of good quality the trees must be kept close and thick, otherwise the stem becomes knotty and weak. Trees of the latter description have sometimes to be sold for so little as 2d. a cubic ft. (Ireland), at which price it cannot possibly pay to grow it.

With the exception of the Silver Fir, the Spruce forms in Central Europe a more full-wooded bole than any other Conifer. This point is of no little importance, because the technical utility, and consequently the market value, of long logs depends to a great extent on the proportion which the diameter of the top-end bears to that of the butt-end. Thus, whilst the *form-factor* of Silver Fir ranges from 0·44 to 0·57—the ideal (cylindrical) bole being = 1·00—that of Spruce varies from 0·41 to 0·58, of Larch from 0·33 to 0·51, and of Douglas Fir from 0·39 to 0·46.

Spruce-wood is full of numerous microscopic resin-ducts, and often also contains hollow spaces filled with resin. Wood of the best quality is of a reddish-white colour; but colour, texture, weight, toughness, elasticity, and general durability are to a great extent dependent on the soil and situation in which the trees are grown. There is no marked change between sapwood and heartwood, as in the case of Larch and Scots Pine.[1]

Spruce is a very light wood, having a sp. gr. of 0·76 when green and 0·45 when seasoned, and is capable of being easily floated immediately after being felled. But, for a Conifer, it is comparatively hard: it ranks between Elm, Beech, and Sessile Oak on the one hand, and Silver Fir, Horse-Chestnut, Alder, and Birch on the other. Along with the Silver Fir, it heads the list of woods that are easy to split; whilst it ranks only after the Yew and Larch with regard to elasticity. In general durability it slightly surpasses the Silver Fir, and when grown at high elevations, so that its annual zones are narrow and its stem full of resin, it is classifiable as a durable wood, although still ranking below Larch and even Scots Pine timber that is not of the first quality.

Soil and Situation.—This tree is nearly as hardy in Britain as the Scots Pine. It grows best on cool land having a moist subsoil, and in a low-lying and rather sheltered part. On high sites—especially if the soil be thin and dry, or if much exposed to strong or cutting winds—it is liable to be blown down,[2] and seldom grows to large timber. It grows best in sheltered hollows with good deep soil, and a cool and moist but not wet subsoil, and can there attain from 80 to 100 ft. in height, and 2 to 3 ft. in diameter. It grows well on moss-land, after it has been drained. It makes moderate demands on the soil for mineral food, and at the same time in reality only limited demands as to water for transpiration—although this may appear erroneous.

Continental Notes.—The experience of Continental sylviculturists with regard to Spruce is very much greater than our own. There it has been found to thrive best in a cool, damp, humid atmosphere; and the drier the climate of any particular locality, the greater are the demands made for soil-moisture. Hence it is essentially a tree of the mountains, in spite of its shallow root-system.

While making rather more demands on the general quality of the soil than the Pines, it can thrive on land that will not produce profitable crops of broad-leaved trees; and as it is a densely-foliaged, soil-protecting tree, it

[1] It is worthy of note that, both in coniferous and deciduous trees, any very prominent and immediately perceptible distinction in the nature of heartwood of a markedly different colour from the younger wood seems to have some very close connection with the formation of a pronounced tap-root, and with very unmistakable demands for light and for a large individual growing-space. This constant coincidence requires investigation.

[2] If it be planted along the wind-swept edge of woods it develops a very firm root-system on the outer side, and makes a good protective fringe. It is used in Germany for this purpose, and generally answers it well, though White Spruce does still better.

gradually (under proper treatment) improves the land by storing up nutrients and enhancing its future productivity. Its finest growth is attained on sandy-loamy soil, but it can do well on moist sand, or even on somewhat tenacious land. Spruce is almost sure to thrive wherever a certain degree of soil-moisture is indicated by weeds like foxglove, epilobium, ragwort, and succulent grasses.

In Britain, Spruce does not grow anything like so well as in Central Germany. This is probably due to the fact that both in its true northern home and also over all its southern area of distribution it has a long period of complete winter rest, accompanied by a very low temperature for two or three months at a time; whereas in Britain, on the contrary, the autumn is often long and mild, and there is seldom any lengthy period of continuous hard frost, such as is characteristic of the climate in places where Spruce is indigenous.

Cultivation.—Spruce is propagated by seed in much the same way as Scots Pine. The cones ripen in early spring, when they should be gathered; otherwise the harvesting and sowing of the seed are as detailed for Scots Pine (see p. 201). The Spruce seedlings, however, are much slower in growth than Scots Pine. They should remain two years in the seed-bed, and will generally require three years in the nursery-rows before they are fit to plant out,—and even longer if wanted of large size. It transplants easily. Spruce does not answer as a nurse for hardwood trees. Robinia, Larch, Birch, and Scots Pine are far preferable, as they cast less side-shade around them; and Spruce has the additional disadvantage of forming very fibrous and matted roots, which keep the air and moisture from penetrating into the soil to the deeper root-systems of the hardwoods. Like all the densely-foliaged Conifers, Spruce thrives well when planted pure as a timber-crop; but it is often preferable to grow it with other trees in mixed woods. It then not only forms a finer stem, but it is also less exposed to the danger of being thrown during storms, or of being attacked by insects or fungous diseases.

Sylvicultural Characteristics.—As is indicated by its shallow root-system, Spruce is more naturally adapted for growing on mountain-sides than on alluvial deposits of light soil, where a tangled mass of shallow surface-roots could afford it little support during storms, more especially when south-western winds come after the lofty crown of foliage has been soaked with moisture and the ground sodden with rain. It is not at first of such quick growth as the Scots Pine, but develops more quickly afterwards. It differs greatly from Scots Pine in its relation to light; for it is a *shade-enduring* species, content with a comparatively small growing-space. It therefore remains in closer canopy, and not only protects but also improves the soil. But the same sylvicultural advantages may also be attained by means of the Douglas Fir, which is a more profitable tree than Spruce to grow in Britain.

Local markets for wood will, of course, in each case determine the age at which crops of Spruce should be utilised; but on the Continent a rotation of sixty to ninety years is held to give the largest profit. In forming young woods of Spruce, planting is preferable to sowing: the plants should be put out between the ages of two and five years, at a distance of about 4 ft. by 4 ft.

(2) THE BLACK SPRUCE or BLACK AMERICAN SPRUCE, *Picea nigra* Link.

SYNONYMS—*Abies denticulata* Poir.; *Pinus nigra* Ait.; *P. Mariana* Du Roi; *P. marylandica* Hort.; *Abies nigra* Michx.

Specific Character.—*Leaves* solitary, spreading regularly all round the branches, somewhat 4-sided, very short and stiff, of a sombre dark-green, ½ in. long, thickly set, and erect. *Branches* horizontal, or in the case of old trees very slightly drooping at the ends. *Cones* pendulous, egg-shaped, 1½ in. to 1¾ in. long, and ¾ of an inch broad, deep purple in colour when young but of a reddish-brown when ripe. *Seeds* small, with a little stiff wing (Gordon).

Distribution.—This tree is indigenous to North America, from Canada down to South Carolina and California; but it is commonest between 53° and 54° north latitude. It is also abundant on stiff lands in Lower Canada, where, intermixed with Hemlock (*Tsuga*), it forms large woods,—as also intermixed with Weymouth Pine and various broad-leaved trees, in the valley of the Ottawa. It was introduced into Britain about 1700.

Description.—On deep soil it often grows from 80 to 100 ft. high; but it seldom attains more than 24 in. diameter. It is a tall slender tree with a pyramidal crown, whose branches spread horizontally, and frequently droop at the ends in old trees. The stem has usually a smooth, blackish bark, is very straight, and tapering. It has an open and airy appearance, from light being admitted between the whorls of branches. These are never of a massy or heavy character, like those of the Common Spruce, but are light and pointed, each tier distinctly showing its outline. Its light spiral form and dark-coloured foliage contrast agreeably with trees of a denser habit, and especially with those having light-green foliage.

Economic Value.—In America the timber is valued for its strength, lightness, and elasticity, and is durable. It is extensively used for house-building and fencing. But it is seldom of large dimensions, and it is only an ornamental tree in Britain.

Soil and Situation.—It is quite hardy in Britain, and grows on a great variety of soil. Good specimens of it may be raised on almost any land that is not too light, dry, or exposed; but it thrives best on deep soil, with a moist subsoil, and in a low-lying, sheltered situation.

Cultivation.—The seed should be sown on light, dry, well-prepared soil, and in a warm and sheltered situation. The seedlings should stand for two years before being transplanted into the nursery-beds, where they may remain for two, three, or four years, according to the size of plants desired for planting out. When large transplants are required, it is advisable to transplant them once a-year in the nursery-beds, so as to produce fibrous rootlets; otherwise long roots are formed, and when removed without previous transplanting, the plants find difficulty in establishing themselves.

(3) THE WHITE SPRUCE, *Picea alba* Link.

SYNONYMS—*Abies glauca et curvifolia* Hort.; *A. canadensis* Mill.; *Pinus alba* Ait.; *Abies alba* Michx.

Specific Character.—*Leaves* solitary, incurved, sharp-pointed, glaucous, 4-cornered, and scattered round the branches; about ¾ in. long, but frequently longer, and not very thickly set on the branches. *Branches* compact, and rather dense. *Cones* oblong-cylindrical, 2 to 2½ in. long, and rather more than ½ in. broad at the thickest part, slightly tapering to the point, pendulous, and not very firm (Gordon). When the cones are ripe, they are of a lightish-brown colour.

Distribution.—This species is also a native of North America, from Canada to Carolina, but is much less common there than Black Spruce. It is generally found on dry light lands, growing along with Weymouth Pine. It was introduced into Britain about 1700.

Description.—This is easily distinguished from any other species of Spruce by the lighter colour of its leaves, which are of a somewhat hoary-grey tinge,—hence its name. Even where indigenous it is not a large tree, for it is hardly ever over 45 or 50 ft. high, or more than 12 to 14 in. in diameter. It is a very ornamental tree, however, forming a perfect pyramid when standing alone. If planted in front of Sugar-Maple having a background of Austrian or Corsican Pine, the autumn colourings will be admirable—the contrast of the grey of the White Spruce, the yellow, red, and crimson of the Maple, and the dark-green of the Pine producing a very brilliant effect.

Economic Value.—On the heaths of Denmark and the dunes of Jutland it is largely used as a protective fringe or "shelter-belt" round plantations, and is considered the best of trees for this purpose. Even in America its timber is not valued, and the tree is purely ornamental here.

Soil and Situation.—It thrives best on dry sloping banks, on deep, light soil; but it will also grow on heavy land, though it never does so well there. Like Black Spruce, it prefers a sheltered situation; but it cannot bear the side-shade of other trees.

Cultivation is in all respects the same as with the Black Spruce.

(4) THE MENZIES or SITKA SPRUCE, *Picea Sitchensis* Carrière.

SYNONYMS—*Pinus Menziesii* Dougl.; *P. sitchensis* Bongard; *Abies Menziesii* Loud.; *A. sitchensis* Lindl.; *Picea Menziesii* Carr.

Specific Character.—*Leaves* solitary, thickly scattered on the young shoots, narrow, linear, rigid, sharp-pointed, and incurved, rich vivid green above and quite silvery below, from ¾ to 1 in. long, soon falling off after the first season, and leaving the old branches very naked, warted, and with a jointed appearance. *Buds* ovate-pointed, and covered with resin. *Cones* 3 in. long, and 1 to 1¼ in. broad, pendulous, cylindrical, blunt-pointed, and with the scales loose and not compact. *Bracteas* small, and hidden in the scales; *seeds* very small, and winged (Gordon).

Distribution.—This fine Spruce was introduced from America by Douglas in 1831, who named it in honour of a previous pioneer in the American woods. It is found between 40° and 57° north latitude, and occurs in great abundance in Northern California, on Sitka Island, and in the Shasta country. It ascends the Rocky Mountains to a height of 7000 ft.

Description.—This highly ornamental tree is of a pyramidal habit of growth, thickly branched, and covered with dense foliage, having a beautiful silvery-green aspect. It is hardy, and very rapid in growth. In California it grows to a height of nearly 200 ft., with a clean bole of 100 ft., and a girth up to 30 ft. Its rapidity in growth is sometimes remarkable. At Shelton Abbey (Co. Wicklow) one specimen girthed 81 in. at twenty-seven years of age (1903), or 3 in. a-year on the average (measured at 5 ft. up). This rate of growth is almost exactly the same as that of a Douglas Fir on the same estate (see p. 249). The largest Menzies Spruce reported in 1903 (58 years, in Perthshire) was 111 ft. high and 13⅓ ft. in girth. In 1891 it was 96 ft. high and 11 ft. in girth (Somerville). It is impatient of shade from above, but can thrive well in the side-shade cast by other species of equal height.

Economic Value.—The timber is hard, firm, and durable. On the Continent it is ranked between the Douglas Fir and the Common Spruce as to quality.

With the sole exception of the Larch, this tree and the Douglas Fir (but especially the latter) are probably the most important coniferous timber-trees that have ever been introduced into Britain. They are certainly the most important introduced from North America at any time, and the most important trees introduced into Britain during the nineteenth century.

Soil and Situation.—Like all the other Spruces, it thrives best on cool, moist, loamy land, though it does well on any soil that is not altogether too light and dry.

Continental Notes.—Although doing fairly well on dry soil, it appears to thrive best on fresh, mild sandy or loamy land, and can even do well where it is too moist for the Common Spruce. When woods are formed by sowing, some light nurse, like Larch or Birch, is needed to protect the young plants against drought and late frost; but it soon outgrows this sensitiveness, and is then a very hardy species. It is, however, best to form plantations with good stout four- or five-year-old transplants. Owing to its prickly foliage, it is not nibbled by deer. The growth of the seedlings is somewhat slow at first, but from the third year onwards it develops more rapidly than the Common Spruce, and during the pole-wood stage of growth it sometimes averages leading-shoots of nearly 5 ft. long over a series of years.

The Sitka Spruce is quite hardy against frost. No other foreign tree except the Douglas Fir can be so much recommended as this for planting on a large scale; and it is even preferable to the Douglas Fir, because it is much less exacting as regards soil and situation (Schwappach).

Cultivation.—It is raised much in the same way as the Common Spruce. In the absence of seed, plants can be raised from cuttings.

(5) THE BLUE or PRICKLY SPRUCE, *Picea pungens* Engelmann.

Specific Character.—*Leaves* on prominent cushions, close, strong and prickly, 6 to 12 in. long, grey-green to blue-white, with 2 resin ducts. *Young shoots* yellowish-brown, smooth. *Buds* (terminal) large and thick, with broad scales bent back. *Cones* 3 to 4 in. long, light-brown. *Scales* with a wavy edge.

Distribution.—The Blue Spruce is a native of the Rocky Mountains, where it grows scattered among other trees in mixed forests at 6500 to over 9000 ft. elevation, and reaches a height of 150 to 160 ft. in moist valleys. It was introduced into Europe in 1863.

Description.—This very hardy and quick-growing tree is, on account of its pretty foliage, one of the most beautiful Spruces for the ornamentation of gardens and parks. Deer will not browse on it, because of the prickly foliage.

Soil and Situation.—It thrives wherever the Common Spruce can, but will also do well on wet, swampy land that is too moist for the latter.

Cultivation.—As with Common Spruce.

(6) THE HIMALAYAN SPRUCE, *Picea Morinda* Link.

SYNONYMS—*Pinus Khutrow* Royle; *P. Smithiana* Lamb.; *Abies Smithiana* and *A. Khutrow* Loud.

Specific Character.—*Leaves* singly at nearly equal distances round the shoots, mostly four-sided, somewhat curved, from 1½ to 2 in. long, and having very sharp points. Its *branches* spread out horizontally, but those nearest the bottom of the tree are somewhat bent downwards; the lateral branches are very numerous, slender, and drooping. The *cones* are pendulous when matured, from 5 to 6 in. long, and about 2½ in. broad, ovate-oblong, or nearly cylindrical; they have very even, brown, obovate, rounded *scales*, covered with a glaucous bloom when young. The young cones are at first upright, but owing to their own weight and the slenderness of the branches they soon become pendulous (Gordon).

Distribution.—The Morinda Spruce forms extensive forests on the cool northern slopes of the Himalaya at 7000 to 12,000 ft. above sea-level, whence it extends eastwards into Japan. It was introduced into Britain in 1818.

Description.—It often attains a height of 140 to 160 ft., with a stem of 4 to 6 ft. in diameter, and is a tree of graceful habit. On young trees the branches have an upward tendency, but with age the lower branches assume a horizontal position from their own weight, and finally droop, while branchlets again droop downwards from these in a very graceful manner. It is hardy in Britain, though purely of arboricultural interest. The largest specimens recorded (Somerville, 1903) are 74 ft. high and 9 ft. girth (57 years, Kent; in 1891 it was 71 ft. high and 8 ft. in girth), and 76 ft. high and 8 ft. girth (70 years, Linlithgow).

Economic Value.—Its timber is soft and not durable.

Soil and Situation.—Like the majority of Spruces, it prefers a rather moist and deep soil, but without any stagnant water in the subsoil; and it does best on a cool northern aspect. Even in our humid, temperate climate it does not thrive when planted on warm southern aspects. It is less capable of bearing shade than the majority of Spruces, and makes considerable demand for individual growing-space. As, however, this tree possesses no sylvicultural value for Britain, its demand for light is of no great consequence; for all trees cultivated with a view to the full development of their arboricultural qualities need a much larger growing-space than they could have as crops of timber grown for profit.

Cultivation.—The seed is sown in the same way as the seeds of Spruce and Scots Pine; and after seedlings have come up they are transplanted into nursery-rows as detailed for the latter. In the absence of seed, plants may be propagated from cuttings; but they do not grow so freely as seedlings.

(7) THE ORIENTAL or SAPINDUS SPRUCE, *Picea orientalis* Lk.

SYNONYMS—*Pinus orientalis* Lamb.; *Abies orientalis* Poir.

Specific Character.—*Leaves* solitary, very dense, partially 4-sided, covering the branches on all sides, deep-green on both sides, narrow, but not sharp-pointed, from ¼ to ½ an inch long, and rather stout. The *branches* are straight, slender, and well covered with foliage. The *cones* are pendulous when full grown, cylindrical, tapering regularly from near the base to the point, which is small, 2½ to 3 in. in length, and about ¾ of an inch broad at the widest part, which is near the base. *Bracteas* shorter than the scales, and enclosed (Gordon).

Distribution.—The Oriental Spruce is found on the Black Sea coast, on the lofty mountains of Imeretia, in Upper Mingrelia, and the neighbourhood of Teflis, forming pure forests in close canopy between Guriel and the Adshar Mountains, at an elevation of 4200 to 4800 ft. above the sea-level. It was introduced into Britain about 1838.

Description.—It is as hardy as the Common Spruce, and is comparatively insensitive to our severest winter frost. But in Britain it is rather slow-growing, and seldom makes more than a foot in height in one year, although under specially favourable conditions it often grows more rapidly. Where indigenous it attains a height of 70 to 80 ft.; but in Britain it seldom exceeds 50 to 60 ft. Clear drops of resin, called "**Sapindus tears,**" exude from the tips of the young twigs. The largest specimen (1903) is 75 ft. high and 6¼ ft. in girth (52 years, Carnarvon; it was 58 ft. high in 1891).

Economic Value.—The timber is full of resin, and is said to be tough, elastic, and durable; but its slow rate of growth makes it unsuitable for British woodlands.

Soil and Situation.—Its demands as to soil and situation very closely resemble those of the Menzies or Sitka Spruce.

Cultivation.—The seeds are almost black, and have short, broad wings. Sowing and the treatment of young plants in the nursery are the same as for Scots Pine.

(8) ALCOCK'S SPRUCE, *Picea Alcoquiana* Masters.

SYNONYMS—*Abies ajanensis* Lindl.; *A. Alcoquiana* Hortor.; *Picea jezoensis* Carr.; *P. Omorica* Pan.; *P. ajanensis* Fisch.; *P. bicolor* Mayr.

Specific Character.—*Leaves* solitary, half an inch long, and half a line broad, curved, rigid, 4-sided, sharp-pointed, and crowded on all sides of the shoots. They are deep-green above, somewhat concave, and streaked with glaucous bands below, and are on twisted footstalks, placed on diamond-shaped cushions along the shoots. *Cones* solitary or subaggregate, oblong-cylindrical, obtuse at the ends, 2 in. long and 4 in. in circumference.

Distribution.—The Alcock Spruce is found on the sacred mountain Fusi-Yama, on the Island of Nippon, in Japan, at 6000 to 7000 ft. elevation, where it forms a noble tree, with very small leaves, glaucous on the under side.

Introduced in 1861, it was named after Sir Rutherford Alcock, then British minister in Japan. This species is often mixed up in gardens with *P. ajanensis.* The latter is believed to be related to the Omorica Spruce (*Picea Omorica* Pan.), which was discovered in Servia in 1872 by Professor Pancic of Belgrade. The Ajan Spruce (*Picea ajanensis* Fisch.) is found in the drainage of the Amur and in Mongolia. Together with the Menzies or Sitka Spruce, these Omorica species exhibit slight botanical differences both from Spruces and from Silver Firs, so that it is not improbable they may soon be formed into a genus *Omorica* by themselves. Their bark is scaly like that of Pines, and not smooth as with Silver Firs and other Spruces. But *P. Alcoquiana* really belongs to a different tribe from the Menzies, Ajan, and Omorica species.

Description.—In Japan this is a large tree, over 100 ft. high. It is hardy in Britain, and forms a beautiful, silvery-foliaged tree of graceful habit.

Economic Value.—The wood resembles that of the Common Spruce, but is somewhat harder and more durable. The tree is, however, of purely arboricultural interest in Britain.

Soil and Situation.—It is accommodating as to soil and situation, provided the former be not wet, nor the latter exposed to strong winds. Fair specimens of it are to be met with throughout Britain on a great variety of soil, and apparently in healthy growth.

Cultivation.—The seed is sown in the same way as that of the Common Spruce; but plants can also be raised from slips.

(9) THE RED SPRUCE, *Picea rubra* Link.

SYNONYMS—*Pinus rubra* Lamb.; *Abies rubra* Poir.; *A. nigra var. rubra* Michx.; *Picea rubra* Carr.

Specific Character.[1]—*Leaves* solitary, very slender, awl-shaped, rigid, sharp-pointed, thickly and regularly scattered all round the branches, somewhat 4-sided, ½ an inch long, and of a glaucous, pale-green colour. The *branches* are horizontal and slender. The *cones* are oblong, egg-shaped, tapering regularly to both ends, pendulous, about 1 in. long and ½ an inch broad, and of a reddish-brown colour (Gordon).

Distribution.—The Red Spruce abounds throughout Nova Scotia, Newfoundland, and the northern parts of North America. It occurs extensively around the Hudson Bay territory, and extends into the Arctic zone, where, as a shrub, it is to be found at the limit of tree-growth. It was introduced into Britain in 1755.

Description.—It is a tall, handsome tree. On good, deep, loamy land in Northern Canada it attains over 80 ft. in height, and is a fine pyramidal tree clothed from top to bottom with branches and foliage. Here it is of poor growth.

Economic Value.—The timber is reddish, hard, and durable, and is much used in Newfoundland. The tree is purely of arboricultural interest in Britain.

Soil and Situation.—It is in all respects hardy enough for our climate, and can thrive even in the north of Scotland ; but it needs a good, deep, and rather dry soil, and a sheltered situation, to do well.

Cultivation.—It is easily raised from seed sown in the same way as that of the Common Spruce. The seeds are very small, and should therefore not be covered with more than, at most, about ⅛ an inch of fine earth. As the seedlings are small at the end of the first year, they should be allowed to stand two years in the seed-beds before being transplanted into the nursery-rows.

3. HEMLOCK, *Tsuga* Endl. (LINNÆAN SYSTEM, MONŒCIA MONADELPHIA).

The genus **Tsuga** comprises 6 species, of which 3 are indigenous to North America and 3 to Eastern Asia. None of them possess any sylvicultural value in Britain ; but they are of arboricultural interest. Like the Spruces, the Hemlocks have their leaves persistent for several years.

Generic Character.—Evergreen trees, with flat or angular, stalked leaves proceeding from prominent cushions (as in *Picea*), generally spreading, distichous or apparently so, but erect and in many rows in *T. Pattoniana*. One resin-canal runs through each leaf beneath the midrib. Buds scaly. Male flowers lateral. Stamens on stalked heads. Anthers crested, opening lengthwise. Pollen two-lobed (discoidal in *Pattoniana* Engelmann). Seeds very small, wing obovate. Female cones terminal. Scales persistent, more or less woody (Masters).

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[1] This is a very indistinctly defined species, differing from *P. nigra* only in having larger and differently shaped staminate flowers and longer and dark lustrous-green leaves, and in being a larger tree growing only on well-drained hillsides, whereas *P. nigra* has bluish and often very glaucous foliage, and grows on mossy bogs. Very little is known of Red Spruce in Britain, the few specimens named as such affording, in the absence of cones, no certain data for identification (Veitch's *Manual of Coniferæ*, 1900, p. 451).

(1) THE COMMON or CANADIAN HEMLOCK, *Tsuga canadensis* Carr.

SYNONYMS—*Pinus canadensis* L. ; *Abies canadensis* Michx. ; *Picea canadensis* Lk.

Specific Character.—*Leaves* solitary, flat, and irregularly disposed in two rows, from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch long, downy when young, rough at the margins, blunt-pointed, bright, vivid light-green on the upper surface, and with two silvery stripes underneath on each side of the midrib. *Branches* are numerous, slender, and downy when young, spreading, and rather flat. *Cones* are pendulous on the extremities of the branches, from $\frac{5}{8}$ to $\frac{7}{8}$ of an inch long, and from $\frac{3}{8}$ to $\frac{4}{8}$ of an inch broad, of an oval shape, green when young, but brown when ripe. *Bark* smooth, and of a light colour (Gordon).

Distribution.—This tree grows nearly all over Canada up to 49°, and throughout most of the northern and eastern states of North America. It is one of the commonest trees in the Canadian woods, from Quebec westwards to Lake Huron, and generally occupies banks of rivers and edges of swamps. It is also sometimes found on dry lands, but then the trees are smaller than when growing on a cool, deep, moist soil. It was introduced into Britain in 1736.

Description.—This is one of the handsomest trees in the American woods. Up to about forty years of age it is of a remarkably graceful habit, from the uniform disposition of its slender branches all round the stem, pendulous at the ends and thickly covered with light-green leaves. As the trees approach maturity the branches become larger and stronger, and stand out horizontally like those of the Cedar of Lebanon. In the Canadian woods it generally grows to about 70-80 ft. high, while trees over 100 ft. in height and with stems of from 4 to 5 ft. in diameter are not uncommon. Here it does not exceed 60 to 65 ft. It is quite hardy in Britain, though it requires a sheltered situation to attain its best growth.

Economic Value.—Even where indigenous, the wood is not at all valuable, and is used only for rough planking. Its bark, however, is used all over Canada for tanning leather. In Britain it is merely of arboricultural interest.

Soil and Situation.—It thrives best on a deep, fresh to moist soil and in a sheltered situation.

Cultivation.—It is grown from seed imported from America. It ripens in early spring, and should be sown in April in light soil on sheltered beds ; and as the seed is small, it should only be covered slightly with earth. The seedlings should stand two years in the seed-beds before they are transplanted into the nursery-rows, where they may stand for two, three, or four years, according to the size of plants wanted. But if required of large size, they should be frequently transplanted in the nursery, to increase the number of fibrous roots. Otherwise they cannot be planted out safely.

(2) THE CALIFORNIAN HEMLOCK, *Tsuga Mertensiana* Carrière.

SYNONYMS—*Pinus Mertensiana* Bongard ; *Abies Mertensiana* Lind. and Gordon ; *A. Albertiana* Murray ; *Tsuga Albertiana.*

Specific Character.—*Leaves* green, glaucous beneath, irregular in size, from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch in length, and about $\frac{1}{16}$ of an inch broad ; they are solitary, grow spirally round the branch, though disposed in an alternate manner, are flat, slightly canaliculate on the upper side, with a midrib on the under one generally blunt-pointed, and having a very short footstalk, and are rather thickly placed on the branchlets. *Branches* very numerous, slender, and more or less bent downwards at the ends ; branchlets very slender, flexible, long, drooping, and somewhat downy when young. *Cones* nearly 1 in. in length, pale-brown, solitary, oblong-ovate, without any footstalk, and pendulous at the ends of the shoots.

Distribution.—This tree occurs throughout Oregon, Northern California, British Columbia, and Vancouver Island. The seed was first sent to Britain by Jeffrey in 1851, under the name of *Abies taxifolia*. It was next supposed to be Bongard's *Pinus Mertensiana*, described in Gordon's *Pinetum* under the name *Abies Mertensiana*, by which it is still extensively known. It was next believed to be a new species, and was named after the late Prince Consort, and for a time known by the specific name of *Albertiana*. The Conifer Conference of 1891, however, adopted the name *Tsuga Mertensiana*.

Description.—This tree grows in California from 100 to 150 ft. in height, and with a stem 4 to 6 ft. in diameter. It bears a dense mass of foliage on long, slender, drooping branches, and much resembles the Common Hemlock, but is of much freer growth and more upright habit from its earliest years. It is rapid-growing and hardy in Britain, and does well even in Scotland.

Economic Value.—Gordon says that its wood is "white, very soft, and yields but little turpentine"; whilst Brown remarks that "the timber is said to be firmer, finer, and straighter-grained than the Canadian Hemlock Spruce." But in any case the tree is only of arboricultural interest.

Soil and Situation.—It is accommodative and grows rapidly in most soils, but seems to thrive best on deep, moist land; while on light, dry land it is often rather stunted.

Cultivation.—It can easily be grown from seed, or else from cuttings.

(3) PATTON'S HEMLOCK or THE CALIFORNIAN SPRUCE, *Tsuga Pattoniana* Engelmann.

SYNONYMS—*Abies Williamsonii* Newberry; *Abies Pattoniana* Jeffrey; *Picea Pattoniana; Hesperopeuke Pattoniana* Lemmon.

Specific Character.—*Leaves* solitary, ranged spirally round the branchlets, not close together, short, with the margin slightly toothed or serrated towards the point, from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch long, boat-shaped in their section, dark-green above, curved, not silvery below. The *buds* are small and conico-ovoid. The branchlets are pubescent. The *cones* are produced at the points of the branches, and are from 2 to $2\frac{1}{2}$ in. long, cylindrically oblong, tapering at both ends, but most so at the top, nearly $\frac{3}{4}$ in. broad, and pendulous. The *branches* are pendulous. The *bark* is rough, and of a grey colour.

Distribution. — This species was found by Jeffrey on the Baker and the Cascade Mountains, in California, at more than 5000 ft. elevation. Lobb afterwards found it on the highest peaks of the Sierra Nevada. It was introduced into Britain in 1851.

Description.—In Oregon it grows to an immense size, trees being sometimes 250 ft. in height, with stems above 10 ft. in diameter. Its branches spread out horizontally from the bole, but droop towards their extremities; while the branchlets are thickly set round with solitary leaves of a grass-green colour above, and pale-green below. In its general habit and appearance it resembles the Deodar; but it has thicker branches, is more thickly foliaged, and is even a handsomer tree. It is hardy in our climate.

Economic Value.—From Jeffrey's account of the good qualities of the timber, it seems not improbable that Patton's Hemlock might, like the Douglas Fir and perhaps also the Menzies Spruce, prove of value as an addition to our timber-trees; but this has not yet been proved by experiments.

Soil and Situation.—The remarks made with reference to the Menzies Spruce are generally applicable to this tree.

Cultivation.—As for the Menzies Spruce.

4. THE FALSE HEMLOCK, *Pseudotsuga* Carrière (Linnæan System, Monœcia Monadelphia).

Generic Character.—The genus *Pseudotsuga* presents closer resemblances to the Silver Firs than to Spruces and true Hemlocks (see table on p. 196). Masters remarks that—

A genus [has been] constructed for the reception of the Douglas Fir. The habit and foliage are those of the Silver Firs, the male flowers like those of *Picea;* cones pendent, ripening in the first year; scales persistent; bracts markedly 3-lobed; wing of seed narrow, pointed; cotyledons 5-7, 3-sided, entire as are the primary leaves. It differs from the Spruce in the foliage. The structure of the wood is quite distinct.

Only one species (consisting of two varieties) has been found and introduced into Britain. But it promises to become a very important forest-tree; for it is of very rapid growth, thrives in our moist climate, and yields an exceptionally large crop of good timber, ranking in quality between Larch and Scots Pine.

THE DOUGLAS FIR, COLUMBIA RED-WOOD, or OREGON PINE, *Pseudotsuga Douglasii* Carrière.

Synonyms—*Pinus Douglasii* Endl. and Lambert; *Abies Douglasii* Lindley; *Picea Douglasii* Link.; *Tsuga Douglasii* Carrière; *Pseudotsuga taxifolia* Britton.

Specific Character.—*Leaves* solitary, flat, entire, narrow, linear, spreading and irregularly two-rowed on the older branchlets, but on the younger trees growing plentifully along their upper side and more sparingly on the under, from ¾ to 1¼ in. long, bluntly pointed, bright-green above and slightly glaucous, and much paler below. *Branches* numerous, irregularly placed along the stem, spreading horizontally, sometimes a little ascending, sending off numerous twigs, and nearly flat. Branchlets long, slender, mostly in two rows, and more or less declining. *Cones* ovate or oblong, terminal at the points of the upper branchlets, solitary, pendulous, yellowish-brown, with many linear, extended, sharp-pointed bracteas, loosely imbricated, from 3 to 4 in. long, and from 1 to 1½ in. in diameter. *Scales* rounded, smooth, leathery, concave, quite entire, thin, and persistent. *Bracteas* linear, three-pointed, the middle one longest and pointed, the two outer ones being comparatively short.[1] *Seeds* small, with a wing fully ⅝ of an inch long.[2]

Distribution.—The Douglas Fir is indigenous to the Rocky Mountains and Vancouver Island, where it forms large forests. It is distributed throughout an area of about 50,000 square miles between 43° and 52° of latitude in North America. It was discovered by Menzies towards the end of the eighteenth century, but it was first introduced into Britain by Douglas in 1828. Its finest growth is in Oregon, where it attains up to 300 ft. in height and 27 ft. in girth. In the Sierra Nevada it ascends to 8000 ft. It is known locally as the *Red Pine* in some parts of America.

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[1] The cones are thus easily recognised from those of any other Conifer, as these prominent seed-bracts, with their prolonged central rib and broader wings on either side, are very distinctive.

[2] For articles on Douglas Fir, see *Trans. Roy. Scot. Arbor. Socy.*, vol. xvi., part ii. (1900), pp. 185-188, and vol. xvii., part ii. (1904), pp. 269-276.

The Colorado variety has been called *P. glauca* (Mayr). It is a tree of the mountains of Colorado, New Mexico, and Arizona. Its needles are shorter, blue to grey-green, and lie close to the shoot; its buds are conical, and its cones short (2 in. by 1 in.), the scales being often bent back (Klein, article on *Forstbotanik*, in Lorey's *Handbuch der Forstwissenschaft*, 2nd edit., 1903, p. 271).

Description.—This is one of the noblest of forest-trees, and the most productive in timber per acre. It is the fastest-growing Conifer imported into Britain. Though it is not yet eighty years since it was introduced, many specimens range from 100 to 130 ft. in height with a proportionate girth, and are the giants of our woods.

The Douglas Fir is, next to the Larch, probably the most valuable tree ever introduced into Britain; and it is certainly the most valuable tree introduced during the nineteenth century. This is more especially true of the dark-green and quicker-growing variety (which also produces the better timber) indigenous to the Pacific coast, where the climate more closely resembles our humid insular atmosphere than does that of the Colorado mountainous tracts, where the light-green variety of slower growth predominates.[1]

Its habit of growth is extremely ornamental, for when it stands by itself it is clothed to the ground with densely-foliaged branches. It flushes its foliage late, and this makes it hardy even in the north of Scotland. The foliage is persistent for 5 to 7 years, as with the Spruce. The Colorado variety is naturally the hardier of the two, but the Pacific is hardy enough for all practical purposes. Its long leading-shoot (often growing from 4 to 4½ ft. in a season) is apt to get broken by wind, but it soon sets a new shoot to take the place of the broken leader. It is of quicker growth than the Larch. On the Blackmoor estate (Earl of Selborne, Hants), in a young mixed plantation (nine to eleven years of age), the finest poles made shoots of 4½ to 4¾ ft. high, while the best of the Larch were growing from 4 to 4⅓ ft. It is a thickly-foliaged tree, and bears close side-shade, though not drip from above. Unless planted closely (4 by 4 ft., or 4½ by 4½ ft. at most) it tends to run strongly into branches, so that to grow clean boles it must be kept close.

The Douglas Fir may be easily recognised from the Silver Fir by the larger pockets of aromatic resin which collect in pustular sacks below the outer skin of the bark, by the longer leaves and the different nature of the marks on their lower surface, and by the delicious aromatic fragrance of the foliage when pressed between the fingers. If experiments were made, this scent contained in the foliage might perhaps even be found to have a commercial value for soap or scent.

The largest specimens recorded (1903) are 127 ft. high and 11½ ft. in girth (73 years, Bucks; it was 120 ft. high and 10 ft. 10 in. in girth in 1891), and 103 ft. high and 9 ft. in girth (58 years, Perth; it was 92 ft. high and 7 ft. 1 in. in girth in 1891). Many ornamental specimens in Ireland show an average increase of about 2 in. in girth a-year, but the largest seen by me was one at Shelton Abbey (near Arklow, Co. Wicklow), planted in 1877 and girthing (1903) 6 ft. 9 in. at breast-height, or an average of 3 in. per annum.

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[1] Besides these two natural bluish and greenish varieties found in the forests of North America, several varieties are occasionally cultivated, such as (1) *P. D. fastigiata*, with a conical crown of foliage; (2) *P. D. Standishiana*, with foliage silvery-white on the lower side; (3) *P. D. macrocarpa*, bearing large, long cones; and (4) *P. D. pendula*, with long hanging branches of 9 or 10 ft. in length.

Economic Value.[1]—As with other species of timber, the quality of the wood much depends on whether the soil and situation are favourable or not. The best wood comes from moderate elevations on the western slopes of the Rocky Mountains, and is of great durability. Whilst the sapwood is white, the heartwood of *Red Pine* is reddish and of excellent quality, somewhat resembling Yew-wood in texture. It is used for ship-building, house-building, carpentry, furniture-making, and general purposes.

The Californian timber, imported under the trade names of "Oregon Pine" or "Columbia Red-wood," is beginning to take the place of Baltic Pine to some extent. The good, reddish timber produced by the Douglas Fir in Britain ranks about midway between that of Larch and of Scots Pine (see page 268). As it produces a larger crop of timber per acre than any of the other Conifers, this adds greatly to its importance as one of the best of trees to plant with a view to profit. It must be planted close and kept thick; but it will yield large poles in thinnings from the age of fifteen to seventeen years onwards. The stem is full-wooded, having a form-factor of 0·4 to 0·45. The wood of the Pacific variety is better than that of the Colorado variety, and is the more suitable for planting in a damp and comparatively mild climate (*e.g.*, as in Ireland).

Unfortunately, however, Douglas Fir has, like the Larch, its special fungous diseases. Such occasioned by *Botrytis cinerea* and *Phoma pithya* have already been reported from several localities; and if they become serious, they may greatly depreciate the value of the tree for cultivation in Britain.

Soil and Situation.—Although not exactly accommodating, the Douglas Fir cannot be called exacting as to soil. But it certainly thrives best on a deep, fresh loam or sandy loam, and in a sheltered situation with a humid atmosphere such as the west coast of Britain. It also does well, however, on heavy land if it has fair natural drainage, but not on chalk or any other kind of limy soil. It is better suited for sheltered, low-lying tracts than Larch, while Larch is the better suited for hilly situations.

Continental Notes.—Larger sylvicultural experiments than in any part of Great Britain have been made with Douglas Fir throughout Northern Germany, and experience there also shows that it is well worthy of cultivation for the rapidity of its growth and the good quality of its timber. In fact, it is there also considered the most valuable of all the non-European trees for woodland crops. Continental experience also indicates that fresh, loamy sands and sandy loams are the kinds of soil best suited to it. But it is said to

[1] This is the most abundant, as it is the most valuable, tree in British Columbia. The average cut of Douglas Fir in British Columbia is over 50,000 ft. per acre, though in some instances more than 500,000 ft. have been cut on a single acre, no trees of less than 2 ft. or more than 5 ft. in diameter being used. Douglas Fir is chiefly valuable for structural purposes, being largely employed in ship-building, bridge-work, and the construction of wharves. It is exported as dimension timber, lumber, spars, masts, and piles. Locally it is used for construction work of all kinds, fencing and railway ties, and in the manufacture of furniture. Its durability, when excluded from the air, adds greatly to its value for pile-work in the construction of bridges and wharves. The bark of the Douglas Fir is largely employed in tanning (Macaun, *The Forest Wealth of Canada*, 1902, p. 37).

do fairly well on dry soil; while wet or marshy land and all situations exposed to late frosts in spring are unfavourable. Depth and freshness seem of much more importance than mineral strength in the soil. The Pacific variety has in North Germany been found sensitive to late frost, and even to early autumn frost for the first five to eight years, while the Colorado variety is hardier against frost but less rapid in growth (being only a little quicker-growing than Spruce).

It bears a considerable degree of side-shade, but suffers greatly from the drip of rain under any heavy direct overshadowing. It is therefore not suited for underplanting except perhaps under very light crops of Oak, Pine, and Larch approaching maturity.

When mixed with other species of trees, it soon outstrips them in growth in height, and then throws a considerable shade across them, which can only be borne by the more distinctly shade-bearing class of trees.

On account of its rapidity in growth, it is particularly well suited for the filling up of blanks in all plantations formed in localities not unduly exposed to late frosts in spring.

For plantations, four-year-old transplants are preferred, which are raised in the same way as Spruce.

Cultivation.—It begins to bear seed of fair quality as early as about the twenty-fifth year, and is a very prolific seed-bearer. In good years the two oldest trees at Scone, raised from the seed first sent home by Douglas (who was trained as a forest apprentice on the Scone estate, and whose monument stands in Scone churchyard), bear about 20,000 cones. The trees have then to be specially protected against squirrels. As large quantities of seed are now produced in this country, a good supply of plants ought to be obtainable at much lower prices than are usually asked. It is unfortunate that Douglas Fir seedlings and transplants are so much dearer than Larch, Scots Pine, and Spruce, because otherwise it would probably (with great future advantage to the country) be planted much more extensively than has yet been done. No tree is easier of cultivation.

The seeds and the seedlings may be sown and transplanted in the same way as Scots Pine and Spruce. If planted in mixture with Larch, it either shoots ahead of the latter and suppresses it, or else (if the Larch be given a sufficient advantage in height at time of planting) the leader of the Douglas Fir gets stripped of needles, and is either badly injured or killed outright by the whipping from the thin side-twigs of the Larch.

The most famous Douglas Fir plantation in Britain is that of about 8 acres in extent at Taymount, seven miles from Perth, originally planted in 1860 with four-year-old Douglas Fir at 12 by 12 ft. (raised from seed produced by the two trees at Scone), and filled up with Larch at 6 by 6 ft. (viz., 1210 per acre: 908 Larch and 302 Douglas Fir). From the first the Douglas Fir had the advantage, and outgrew the Larch: the soil was good and nearly level, not hilly and well drained like what would have best suited the Larch. By 1880 all the Larches had to be thinned out, and in 1887 a further thinning was made of 620 of the Douglas Fir, which were sold by auction for £34.[1] This latter thinning having been premature and heavy, the remaining Douglas Firs threw out strong branches, which involved pruning to a height of 30 to 35 ft. in 1896; and no further thinning has since taken place. In 1888 the plantation was estimated to contain 3738 cubic ft. of wood per acre exclusive of lop and top, showing an average increment of 117 cubic ft. per acre per annum during the thirty-two years since the trees grew from seed. In 1900 a Perth timber-merchant offered 9d. per cubic ft. for the whole timber in the plantation (Larch being 1s. and Scots Pine 6d. per cubic foot locally). As was then estimated, this offer amounted to just about £1600, or £200 per acre for the forty-year-old plantation. The standing crop in 1903 consisted of about 210 trees per acre, with a mean height of 83 ft. and a mean diameter of 16 in., the timber height (down to 3 in. diameter) reaching up to 75 ft. Including four years from the sowing of the seed in 1856, the average annual growth in height has been over 1 ft. 9 in., and the annual growth of wood has averaged 238 cubic ft. per acre. The true cubic contents of the average tree were found to be 50¼ cubic ft., or 39½ cubic ft. by square-of-quarter-girth (British timber trade) measurement; and the total crop per acre would thus be 11,170 cubic ft. true contents, and 8880 cubic ft. square-of-quarter-girth measurement. Taking only 202 trees per acre (for comparison with estimate of 1888), this would show a total of 10,150 cubic ft. true and 7977 cubic ft. square-of-quarter-girth measurement, and a total increment of 7433 cubic ft. (11,171 − 3738) during the fifteen years from 1888 to 1903, *or an average of* 495 *cubic ft. per acre per annum true contents, equal to about* 400 *cubic ft. square-of-quarter-girth measurement, and worth* £15 *at* 9*d. per cubic foot.* Two recent photographs of this plantation are reproduced on opposite page.

The damp climate of Ireland suits the Douglas Fir well. On the Whalley Abbey estate (near Rathdrum, Co. Wicklow) there is a small but instructive plantation of Douglas Fir of about 1½ acres, made in 1885, on good light loam on level ground. Originally formed of Douglas Fir and Thuja at about 6 by 6 ft., the former have quite outgrown and suppressed the Thuja, and in 1903 formed splendid poles ranging from 50 to 60 ft. in height, and up to 27 in. in girth at breast-height. The lower branches of the Douglas Fir, though dead, were still adhering; and from their thickness it seems clear that the proper distance for planting, in order to have stems clean and free from knots at an early age, is 4 by 4 ft., or 4½ by 4½ ft. at most. It is also shown here that at about sixteen to eighteen years after planting the first (and necessary) thinning of dominated stems no longer required to form part of the leaf-canopy will yield good large poles of fair marketable size. Some of the young trees have lost their leaders from wind, but this is little likely to affect the value of the trees as to total yield of timber per acre when mature.

[1] "They are the largest of their age I ever saw. They measure about 60 ft. in length, and many of them are 5 ft. 9 in. in circumference at 3 ft. above the ground. I never knew that in any coniferous trees before."—Mr M'Corquodale's evidence, *Parliamentary Forestry Committee*, 1887. For fuller details concerning this plantation, see *Trans. Roy. Scot. Arbor. Socy.*, vol. xvii., part ii. (1904), pp. 269-276.

Fig. 24.

Douglas Fir Plantation, formed in 1860 (*Taymount, Perthshire*, 1900).

Fig. 25.

Same Plantation (1901), *showing the planting-lines and the stumps of some of the stems thinned out* (*Larch*, 1880; *Douglas Fir*, 1887).

5. THE SILVER FIR, *Abies* DC.
(Linnæan System, Monœcia Monadelphia).

Synonyms—*Abies* Link.; *Picea* Loudon.

Generic Character.—Trees with whorled branches; adult leaves 2-ranked, sessile, narrow, flat, leaving a circular scar on the branch when they fall. *Male catkins* scattered, axillary; anthers crested, opening crosswise; pollen-cells winged. *Cones* erect, maturing the first year. *Bracts* more or less conspicuous, free from the scales except at their base, *seed-scales* becoming detached from a central column when ripe, and each falling separately. *Seed* with a large inseparable wing. *Testa* with resin-canals. *Cotyledons* 4-8, flat, leafy, entire. *Primary leaves* of the same order, but much smaller (Masters).

The Silver Firs are ornamental and are remarkable for their pyramidal symmetry. They are easily distinguished from the Spruce genus by their leaves being more regularly in two rows, by their cones standing upright on the branches and having deciduous scales, and by the seeds being somewhat triangular in form. They are indigenous to Europe, Asia, and America, but are generally found in more temperate regions than where Spruces abound. Silver Firs do best on good deep heavy soil and in a sheltered situation. But they thrive on almost any loamy soil, if not too elevated or exposed. The majority of them are hardy in Britain, and grow freely after they have once established themselves.

There are 33 known species of Silver Firs, 5 of which occur in Europe, 14 in Asia, 15 in North America, and 1 in Africa; the latter and 1 of the Asian species are included in the 5 occurring also in Europe (Willkomm).

They are evergreen, shade-bearing trees, capable of maintaining close canopy either in pure woods or when mixed along with other trees. As the leaves are ranged closely on the twigs and are persistent for several years (see p. 202), Silver Firs cast a deep shadow and keep the soil cool and fresh. They form long, straight, full-wooded stems having a *form-factor* of 0·44 to 0·57, which indicates a higher average degree of good top-girth than any other European conifer. The seed of Silver Firs ripens within a year of the flowering.

(1) THE COMMON SILVER FIR, *Abies pectinata* DC.

Synonyms—*Pinus Picea* L.; *P. Abies* Du Roi; *P. pectinata* Lamk.; *Picea pectinata* Loud.; *Abies pectinata* Link.; *A. alba* Miller; *A. vulgaris* Poir.; *A. taxifolia* Desfontaines.

Specific Character.—*Leaves* solitary, flat, obtuse, two-rowed, and with their points turned up; from ⅝ to 1½ in. long, stiff, and of a shining dark-green above, with two lines of a silvery white on each side of the midrib beneath. *Cones* from 6 to 8 in. long, and from 1½ to 2 in. broad, cylindrical, erect, and axillary, green when young, afterwards reddish, and when ripe of a brown colour (slightly altered from Gordon).

Distribution.—The Silver Fir is indigenous to the mountains of Central Europe, and to the west and north of Asia. It occurs largely in France, Southern Germany, Switzerland, Austria, Italy, Spain, Greece, and the south of Russia. On the Carpathian Mountains it is found at an elevation of more than 3000 ft., and on the Alps at nearly 4000 ft. It was introduced into Britain in 1603.[1]

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[1] A monograph on the Silver Fir will be found in the *Trans. High. and Agric. Socy.* for 1885, pp. 229-243.

Although of spontaneous growth throughout most of Central and Southern Europe, the Silver Fir has nothing like the same distribution as the Spruce. Its northern limit of indigenous growth commences in the western Pyrenees at 43° in Navarre, then trends eastwards along the northern slopes of that mountain-chain, and bends to the north on reaching the hills of Auvergne. From there it passes in a north-east direction across Burgundy and Lorraine to the eastern slopes of the Vosges and across the southern part of Westphalia, then skirts the southern edge of the Harz Mountains, and passes into Saxony and Silesia, to the east of which it reaches its most northerly point at 51° 40′ near Soraw. Its indigenous area forms an irregular ellipse, extending over about 32° of longitude and about 14° of latitude; but within this area there are large tracts where it is not of spontaneous growth, as it does not naturally occur on the warmer plains and lower hill-ranges of the southern portion of its habitat. The most extensive forests of pure Silver Fir are to be found on the northern slopes of the Pyrenees, in the Vosges, the Jura, the Black Forest, Franconia, and Thuringia, at elevations ranging from 1200 to 4000 ft. (Willkomm).

It attains its finest development in the mountainous tracts of Central Europe, where, however, the climate is of an essentially dry, continental character as compared with our damp, insular atmosphere. It would therefore hardly be reasonable to expect from our plantations as large an out-turn in timber as is obtainable from the Silver Fir in Central and Southern Europe, where it produces, along with the Spruce, larger supplies of timber per acre than any other indigenous species of forest-tree.

Description.—The Silver Fir is the largest of all the European trees. It is a noble-looking tree, perhaps too little grown in our plantations. It often attains over 100 ft. in height, with a stem 3 to 5 ft. in diameter. When young it is sensitive to late frosts in spring, which retard its growth considerably; but after young transplants have fully established themselves, and when they have attained a height of about 5 or 6 ft., frost has no further effect on them. They then begin to grow rapidly. If mixed with Spruce, at about fifteen to twenty years of age they generally overtake the latter, and then they maintain the ascendancy. If grown in woodlands, its early sensitiveness to frost can be guarded against by affording it the protection of standard trees, or in young plantations by having nurses of Larch, Scots Pine, or Birch; while for arboricultural purposes the use of stout transplants, whose leading-shoots are above the frost-level, generally obviates danger.

Throughout Western France and Central and Southern Germany, the Silver Fir is one of the chief forest-trees. Often worked with a rotation of 180 to 200 years, it attains a height of over 200 ft. and a girth of 10 to 12 ft. in the woods. At first its crown is pyramidal and very regular; but with advancing age it becomes more irregular and bushy. Its root-system is deep-reaching and spreading, but neither so deep as Larch and Pine, nor so spreading and shallow as Spruce. During the earlier stages of growth the branches, occurring in regular whorls, have a somewhat upward tendency, as in the Spruce; but in older trees they are throughout almost at right angles, and are of unequal length.

The foliage is dense, as the leaves or needles are persistent for eight to ten years. Small pustules filled with resin develop early under the leathery cuticle of the bark; but these are not so long as those formed by the Douglas Fir. On older stems these resin-sacks burst simultaneously, and the resin forms white streaks down the bark.

There is a famous group of Silver Fir in the Duke of Argyll's grounds at

Rosneath. At Drummond Castle there also exists a noble and patriarchal avenue of Silver Firs, but the great north-east storm of 17th November 1893 laid low six of them, which were probably among the finest in Perthshire.

The two largest specimens reported to the Conifer Conference of 1891 were respectively 111 ft. high and $15\frac{1}{2}$ ft. in girth at 5 ft. above the ground, and 110 ft. high with a girth of $17\frac{3}{4}$ ft. The former was growing at Carton, in Kildare, and the latter at Rossdhu, in Dumbartonshire.

Economic Value.—This timber is imported under the name of "Swiss Pine," and is largely used for musical instruments. In Britain the timber of this tree is reckoned about equal to that of Spruce, and is used for the same purposes. But it often produces more timber per acre than the Spruce, and is only excelled in regard to production by the Douglas Fir. Although of a somewhat greater sp. gr. (0·97 green and 0·47 seasoned), the wood of Silver Fir is softer than that of Spruce. It is also less resinous, owing to a paucity of resin-ducts within the medullary rays; but in many parts of the Continent its timber is preferred to that of the Spruce. Neither of them is so durable and good as Larch, Douglas Fir, and Scots Pine.

Soil and Situation.—The Silver Fir thrives best upon a good deep, fresh, and stiffish loam. It is, however, by no means particular as to the quality, provided the soil be deep, and the situation sheltered; and it may be found growing well both on stiff clay and on light land. On rather heavy soil it thrives well in most parts of Great Britain and Ireland up to about seventy years of age; but then it seems to sink into a slow rate of growth, which never becomes quickened again. Measurements of rate of growth collected by me in England, Scotland, and Ireland all indicate maturity at about seventy years.

It does not do well in a wind-swept situation. Its largest yield is in pure plantations, but it is well suited for planting in mixed timber crops; for even if it fail to grow so quickly in the upward struggle for light and air, it is better endowed than most other species for bearing shade and remaining in healthy growth. Owing to its deeper root-system, Silver Fir requires a deeper soil than Spruce; and at the same time it also makes the highest demands among the European Conifers with regard to the amount of mineral food annually withdrawn from the soil. It therefore needs at least a fresh soil, although it requires less water for transpiration than other Conifers (Ebermayer). Continental sylvicultural experience has shown that it thrives best on deep sandy loam; that on light sandy or heavy argillaceous soil its growth is less energetic; and that on wet land with stagnating moisture, or having a limy impervious subsoil, its growth is least satisfactory.

Cultivation.—The Silver Fir is grown from seed in much the same way as Scots Pine and Spruce. The cones generally ripen about the end of October, and the seeds are easily separated on dry, warm days. The seed should be sown rather thinly about the first week of April, as the seedlings are of somewhat spreading habit. They should remain two years in the seed-bed before being transplanted into the nursery-rows. Here also they should stand rather thinly; for when young they require a fair amount of growing-space. They are of slow growth, and need three years in the rows before they are fit for planting out. When the seedlings appear above ground in May and June they generally need protection against late frosts.

Sylvicultural Characteristics.—Silver Fir makes greater demands than Spruce with regard to both soil and climate. It is therefore better fitted for the milder parts of Central and Southern England than for the rawer climate of Northern Scotland. For its normal development a mean temperature during August of at least 66° Fahr. is requisite; whilst a mean temperature during January below 21° Fahr., or over 77° in August, is incompatible with the climatic conditions essential for its growth (Willkomm). As our average temperature in July and August is respectively below 63° and 62°, it therefore follows that the Silver Fir should only be planted out in warm tracts. And, at the same time, its shade-bearing capacity will be less in cold situations than in a mild warm climate. The moister the atmosphere, the less are the demands made for soil-moisture; hence it should thrive in Britain on drier kinds of soil than throughout Central Europe.

When growing in dense woods it begins to produce seed about the sixtieth to seventieth year, although it is not so prolific a seed-producer as either Spruce or Scots Pine. When such woods are regenerated by seed from parent standards, the growth of the seedlings is very slow at first, a ten-year-old Silver Fir being no larger than a four-year-old Spruce; but from about the eighth or tenth year it begins to grow more rapidly in height, and to form more regular whorls than is up till then the case. In Central Europe its growth in height continues very energetic until about the hundredth year, when it begins to decline, and the stems thicken at a quicker proportionate rate. When worked with long periods of rotation exceeding 150 years (as is often the case in the mountain-forests of Central Europe), there is a tendency to the crowns becoming **stag-headed**. But, on the whole, the Silver Fir suffers less than Spruce or Scots Pine from parasitic diseases, although the fungus *Æcidium elatinum* affects both the stems and the top branches of old trees, causing canker and twig-clusters.

Continental Notes.—When new plantations are being formed, Continental experience has shown that the best plants for pure or mixed plantations are four- or five-year-old transplants that have been transferred from the seed-beds to the nursery-lines at two years of age. No advantage is gained by transplanting yearling seedlings into the nursery-beds, for they simply have to stand a year longer there, and during that one year occupy a larger growing-space than there is any necessity for. Two-year-old seedlings can be easily transplanted naked, without balls of earth attached to the roots; but when planting is being carried out in rather dry weather, the roots should be dipped from time to time in a mixture of loam and water to keep them cool and moist. In Southern Germany the two-year-old seedlings are transplanted into the nursery-beds about 3 in. apart in lines, with 5 in. between the rows, when it is intended to plant them out as four-year-olds, or at 4 in. by 8 in. if required as five-year-old plants, or at 5 in. by 7 or 8 in. if wanted at six years of age.

(2) THE BALSAM or BALM OF GILEAD SILVER FIR, *Abies balsamea* Miller.

SYNONYMS—*Pinus balsamea* L.; *Picea balsamea* Loud.; *Abies balsamifera* Michx.

Specific Character.—*Leaves* solitary, entire, or emarginated at the end, irregularly two-rowed, and mostly on the upper part of the branches, or scattered round the leading-shoots, spreading, flat, silvery beneath and bright-green above, ¾ in. long, and thickly set on the branches. *Cones* cylindrical, tapering towards the point, erect on the upper part of the branches or nearly so, 3 to 4 in. long, and about 1¼ in. broad, of a dull violet colour, and sessile. The *bark* of the tree is thickly interspersed with small vesicles containing a clear limpid resin. Points of the cones generally tipped with resin, and also the buds. *Seeds* very small, angular, soft, and only half the size of those of the Common Silver Fir, with a broad, ample wing (Gordon).

Distribution.—This tree is indigenous to Canada, Nova Scotia, and the Northern States of America. There it grows on cold, moist lands and the edges of swamps, and is usually about 40 ft. high, or seldom exceeding 50 to 60 ft., with a stem of 12 to 14 in. in diameter. It was introduced into Britain in 1696.

Description.—It resembles the Common Silver Fir in general appearance, but is smaller. It grows rapidly at first, but seldom lives here to more than about thirty years old, when it seems to mature and die off. It is hardy, and at first much more rapid in growth than the Common Silver Fir, and soon produces shelter for more valuable trees. The bark of the stem is of an ashy-grey colour, while that of the younger branches is of a yellowish-brown, and has a slight bloom. It is very resinous, and yields the "Canada Balsam" used for microscopic work. It is alike insensitive as regards late frosts and hard winter cold. The largest tree reported to the Conifer Conference of 1891 had a height of 68 ft., and a girth of 9 ft. at 5 ft. from the ground. It was growing on the estate of Saltoun, in East Lothian.

Economic Value.—It is too small a tree for its timber to be of much use, even in America; and it is merely of slight arboricultural interest here.

Soil and Situation.—It will only thrive on deep, rich, moist soil, such as best suits the Willows; on light, dry soil it soon dies off. And even on good land it matures and dies off when only about twenty to thirty years of age, although to all outward appearance it may have developed favourably during the first ten or twelve years.

Cultivation.—Cones are produced, and seeds sometimes ripen in Britain; and it may be readily raised from home-grown or imported seed in the same way as the Common Silver Fir. But as the young seedlings of this species grow much more rapidly, they should be transplanted when one-year-old into the nursery-rows, and they do not need to stand so long there before being planted out permanently.

(3) THE LOVELY SILVER FIR, *Abies amabilis* Forbes.

SYNONYMS—*Pinus amabilis* Douglas; *P. grandis* Lambert; *Picea amabilis* Loudon.

Specific Character.—*Leaves* solitary, linear, flat, entire, blunt-pointed, 1 in. long, irregularly and densely two-rowed, incurved on the upper side of the branches, bright-green above and glaucous below. *Branches* irregular on the main stem; lateral branches numerous, tolerably flat, and densely covered with leaves. *Cones* erect, solitary, large, ovate-cylindrical, 6 in. long and 2½ in. broad, slightly tapering to both ends, and woolly when young. *Seeds* angular and soft, with a membranaceous wing (Gordon).

Distribution.—This species is indigenous to Northern California. Jeffrey found it growing there on a gravelly soil at about 4000 ft. elevation and forming a stem of 250 ft. high and 5 ft. in diameter. Its height is usually, however, not above 200 feet. It was introduced into Britain in 1831.

Description.—It is a very densely-foliaged, handsome, and hardy Silver Fir, which assumes a beautiful pyramidal habit as it grows old and large. The largest specimen of this species reported to the Conifer Conference of 1891 had a height of 32 ft., and a girth of 3 ft. at 5 ft. from the ground. It was growing on the Drumlanrig estate (Dumfries), and in 1903 (29 years old) was 44 ft. by 4 ft. 10 in.

Economic Value.—It is not very durable, and even in America its wood is not greatly in request. It is not much cultivated in Britain by arboriculturists, as its shoots are very apt to die off.

Soil and Situation.—It grows well on any loamy soil with a well-drained subsoil. But it appears to do better on heavy than on light soil, and certainly grows better in a low-lying and sheltered than in an exposed situation.

Cultivation.—The seeds being comparatively scarce, plants are usually raised from cuttings grafted on stocks of commoner Firs.

(4) THE LEAFY-BRACTED SILVER FIR, *Abies bracteata* Nuttall.

SYNONYMS—*Pinus venusta* Douglas; *Picea bracteata* Loudon.

Specific Character.—*Leaves* solitary, 2-rowed, linear, tapering to both ends, alternate, flat on the upper side, entire, and sharp-pointed, from 2 to 2½ in. long, and rather more than $\frac{1}{10}$ of an inch wide, bright-green above, ribbed with two silvery white lines below, crowded and scattered at the insertion on the branches, but 2-rowed and extended above. *Branches* in whorls, spreading, slender; lower branches drooping, lesser branches bent downwards. *Buds* composed of large, loose, elliptic, pale-yellow scales, destitute of resin, axillary, and scattered along the branches, but mostly towards the points. *Cones* ovate, erect, on very short footstalks, 4 in. long and 2 in. wide, in great clusters on the upper side of the top adult branches. *Scales* reniform or kidney-shaped, concave, rounded on the upper margin, and stipulate at the back. *Bracteas* wedge-shaped, 3-lobed, the middle one 2 in. long, recurved, particularly those towards the base, which are the longest, while those towards the summit are nearly straight, much shorter, and but little changed in appearance or colour from the ordinary leaves. The lateral lobes are very short, and extend very little beyond the end of the scales. *Seeds* wedge-shaped, soft, and angular, with rather a short, but broad, membranaceous wing (Gordon).

Distribution.—This species was first discovered by Coulter on the Santa Lucia range in Upper California, at an elevation of from 2500 to 3000 ft. above sea-level. Douglas afterwards found it at 6000 ft. elevation on the Californian mountains, in lat. 36° N. It was introduced into Britain in 1857.

Description.—It attains a height of from 120 to 150 ft., and forms stems straight as an arrow, but rather slender, seldom exceeding 2 to 3 ft. in diameter. It can hardly be called a hardy tree, for it flushes its new foliage early in the season, and is liable to injury by late frosts. The largest specimen reported to the Conifer Conference of 1891 had a height of 49½ ft., and a girth of 4½ ft. at 5 ft. from the ground. It was growing at Boconnoc in Cornwall. In 1903 the largest specimens reported were 40 ft. high and 4¾ ft. girth (Gloucester, 37 years), and 49 ft. by 4½ ft. (Cornwall, 30 years).

Economic Value.—Its wood is very resinous, and this may be taken as a good general index of its durability; but the tree is only of arboricultural interest here.

Soil and Situation.—It is said to grow best on a limestone formation. It may therefore, perhaps, be naturally well suited for the chalk and limestone districts of Southern Britain. But it seems to grow well on common loam, though not thriving either on very light or on very heavy soil. It begins active vegetation comparatively early in spring, so that it is probably best to plant it on cold northern or north-western aspects; for it will then not start growing so early as on warmer southern and south-eastern exposures, and will on that account be less likely to be injured by late frosts in spring.

Cultivation.—The seeds of the Leafy-bracted Silver Fir are still scarce. It should be sown in a cold frame, as the seedlings need protection for the first two winters, though later on they become quite hardy, except that the young plants are apt to be damaged by frosts in spring.

(5) THE GREAT CALIFORNIAN SILVER FIR, or VANCOUVER ISLAND PINE, *Abies grandis* Lindley.

SYNONYMS—*Pinus grandis* Douglas ; *Picea grandis* Loudon.

Specific Character.—*Leaves* linear, flat, channeled above, emarginate, or with a small notch at the point, and all irregularly arranged horizontally in double rows on each side of the branchlets, in a more or less pectinate or comb-like manner, on short twisted footstalks ; those forming the upper tiers on each side of the shoots are much the shortest, and little more than $\frac{3}{4}$ of an inch in length, while the majority of those comprising the under series are of various lengths, and nearly double that of the upper ones, but not broader, and all of a deep glossy-green above, and with two silvery-white bands below, between the midrib and thickened margins, both of which are of a bright-green colour. *Branches* mostly in horizontal whorls, flat and spreading ; branchlets glossy, smooth, rather short, compact, and placed laterally in two horizontal rows, and, when young, with quite a varnished appearance. *Cones* erect, cylindrical, and from $3\frac{1}{2}$ to $4\frac{1}{2}$ in. long and $1\frac{1}{2}$ in. broad. *Scales* broad transversely, crescent-shaped, rounded on the exposed part, incurved at the edges, closely placed, tolerably equal in size, downy externally, deciduous when fully matured, and with the small fringed dorsal bracteas entirely hidden by the overlapping scales ; *seeds* small, angular, soft, and with persistent wings, $\frac{3}{4}$ in. long (Gordon, *op. cit.*, Supplement).

Distribution.—This beautiful and magnificent Silver Fir was discovered by Douglas in Northern California ; but Bridges and others have also found it more recently in British Columbia and Vancouver Island. Douglas first sent its seeds to Britain in 1831.

Description.—The Great Silver Fir in California attains 150 to 200 ft. in height, and very much resembles the Common Silver Fir ; but it differs in the young shoots having a glossy look. The foliage is of a deep shining green, and its denseness gives the tree a richly mantled appearance, making it one of the handsomest and most ornamental of Silver Firs. It is hardy enough for Britain, although, like the Common Silver Fir, young plants are liable to be damaged by late frosts in spring. It has a tendency to begin active vegetation early in spring, especially if planted on an eastern or southern exposure ; hence cool northern aspects are better suited for it than warmer exposures. The two largest specimens of this tree reported to the Conifer Conference of 1891 had respectively a height of $83\frac{1}{4}$ ft., with a girth of 3 ft. $8\frac{1}{2}$ in., and a height of 64 ft., with a girth of $7\frac{3}{4}$ ft. at 5 ft. from the ground. The former was growing on the Riccarton estate (Mid-Lothian), the latter at Poltalloch (Argyllshire). In 1903 the two largest specimens reported were 87 ft. by 8 ft. (Perth, 43 years) and 86 ft. by 8 ft. (Bucks, 42 years, with 21 ft. growth in height during the previous ten years).

Economic Value.—Even in America its timber is not used extensively, and here the tree has only an arboricultural interest, though suitable for wood-pulp.

Soil and Situation.—This tree grows best on cool moist soil on flat alluvial stretches, and also on dry land where the atmosphere is sufficiently humid to lessen transpiration. It is as hardy as the Common Silver Fir, and is a favourite with arboriculturists, as there are few more ornamental trees.

Cultivation.—The seed, being comparatively scarce, is usually sown in a cold frame, and the seedlings are generally protected against frost for the first year or two, and then gradually exposed as they grow stronger. When seed can be had in plenty, this species can then be treated just like the Common Silver Fir. It can also, however, be raised by grafting and layering.

(6) THE MOUNT ENOS or GRECIAN SILVER FIR,[1]
Abies cephalonica Loudon.

SYNONYMS—*Pinus cephalonica* Endl.; *Picea cephalonica* Loudon; *Abies cephalonica* Loud., Lawson, Carr.; *A. Apollinis* Link.

Specific Character.—*Leaves* solitary, flat, dagger-shaped, and standing at nearly right angles on every side of the branches, but chiefly on the upper side, of a dark shining green above, and with two silvery lines beneath, tapering from the base to the point, which terminates in a sharp point; *footstalks* very short, dilated at the base, and twisted. *Buds* prominent, stiff, pointed, and covered with a glossy resin. *Branches* very numerous, in regular tiers on the main stem, but branching in all directions in the lateral ones. *Cones* erect, straight, cylindrical, axillary, tapering at both ends, 5 or 6 in. long and 1½ in. broad. *Scales* rounded on the upper part, broad and entire, wedge-shaped below. *Bracteas* projecting beyond the scales, linear-oblong, with the lower end much attenuated, and tapering gradually into a stiff, unequally toothed, and reflexed sharp point at the top (Gordon).

Distribution.—The Grecian Silver Fir is found on Mount Enos or the Black Mountain, the highest in the Ionian island of Cephalonia, at about 3000 to 5000 ft. elevation. It was introduced into Britain in 1824 by General Napier when he was Governor of Cephalonia; but it has since been found on the various different mountains throughout Greece, particularly on Mount Apollo and Parnassus, and on the lofty and rugged Mount Œta.

Description.—In its native mountains this tree produces a large quantity of timber, but does not attain any great length of stem. It grows to about 60 ft. high with a spreading head, and stems are often about 10 ft. in diameter. It is a beautiful object when standing alone in a park, as its numerous and regular tiers of branches stand close together, making it look like an Araucaria. While young, it is of very branching growth, and generally looks more like a large bush than a young tree; but once it gets fairly established, it grows rapidly, and soon assumes a pyramidal habit. It is quite hardy on dry situations at a moderate elevation, but does not thrive on high or exposed localities. It does best near the sea, and is unsuited for high-lying inland tracts, where transpiration is stimulated. In these latter situations it is also liable to injury by frost, as its general vigour is less than under conditions more suited to its special requirements. The largest specimen reported to the Conifer Conference of 1891 was 77 ft. in height, and 11⅙ ft. in girth at 3 ft. above the ground. It was growing at Powderham (Devonshire). In 1903 the largest specimen reported was 73 ft. by 11 ft. (Kent, 57 years; it was 70 ft. by 9⅓ ft. in 1891).

Economic Value.—The timber is close-grained, hard, and durable; but in Britain it can only be grown for ornament.

Soil and Situation.—It prefers a good, dry, light loam to any other soil.

[1] This species is considered by some authorities to be merely a climatic variety of the Common Silver Fir, in the same way as the Siberian Spruce (*P. obovata*) has been regarded as but a climatic variety of the Common Spruce, and as the Corsican Pine (*Pinus Laricio*) is certainly merely a climatic variety of the Black or Austrian Pine (*P. Austriaca*). There are two climatic varieties of the Grecian Silver Fir. One of these, *A. c. var. parnassica* Henk. (the *A. Apollinis* of Link and Carr.), found on the mountains of Greece, and forming pure woods or mixed forests along with Beech and Corsican and Cluster Pines, has shorter, broad, and less hedgehog-like leaves, and long-stalked brown cones about 7 in. in length; whilst the other, *A. c. var. arcadica* Henk. (the *A. Reginæ Amaliæ* of Heldr.), found in the Peloponnesus, and especially on the Arcadian mountains at elevations of 3300 to 4200 ft., has shorter and softer leaves, and smaller cones than the specific Grecian Silver Fir.

On heavy, moist, cold land, where many of the other Silver Firs grow luxuriantly, this species generally remains stunted and bushy; while on light dry loams not much above sea-level, it generally makes leading-shoots of 12 to 14 in. a-year, and sometimes even more.

Cultivation.—Good seed is scarce. When it is obtainable, seedlings can be raised in much the same way as the Common Silver Fir. This Grecian species is, however, very easily propagated by cuttings and also by layering; and when cut back to the stool it often throws out stool-shoots (like some of the three-needled species of Pine).

(7) LOW'S CALIFORNIAN SILVER FIR, *Abies Lowiana* Murray.

SYNONYMS—*Picea Lowiana* Gordon; *P. lasiocarpa* and *P. Parsonsii* of gardens and arboreta.

Specific Character.—*Leaves* long, linear, flat, and quite straight, channeled above, more or less twisted at the base, rather distant, and strictly arranged in two horizontal rows along the shoots, and from 1½ to 2½ in. long, and $\frac{1}{10}$ of an inch broad, blunt-pointed, or with a slight notch in the centre, particularly those on the adult trees, and all of a dull glaucous green above, but much paler, and with two faint glaucous bands below, between the elevated midrib and thickened margins. *Branches* in distant whorls, horizontally placed, and rather slender; branchlets more or less opposite, quite smooth, slender, laterally placed in two horizontal rows, and of a pale-yellowish colour. *Cones* from 3½ to 5 in. long, and 1½ in. broad, erect, cylindrical, obtuse at the point, rounded at the base, of a pale-brown colour, and emitting numerous transparent resinous tear-drops externally, but very similar in shape and general appearance to those of the Vancouver Island Pine, but somewhat larger. *Scales* broad, more or less crescent-shaped, rounded on the outer side, incurved round the margins, woolly on the exposed parts, tolerably equal in size, and deciduous when fully matured. *Bracteas* very minute, dorsally placed at the base of the scales, broader than long, somewhat rounded, wedge-shaped on the upper part, toothed or fringed round the edges, and with a prolonged sharp point in the centre; *seeds* angular, soft, and with a broad hatchet-shaped persistent wing (Gordon, *op. cit.*, Supplement).

Distribution.—This species is found in British Columbia and Northern California, growing for the most part in valleys and on the alluvial banks of rivers. It was introduced into Britain in 1860.

Description.—This species[1] in North America is frequently upwards of 250 ft. high, and with a stem 4 to 6 ft. in diameter. The branches are slender, horizontal, and in whorls; while their foliage is long and light-green for a Silver Fir. It is a hardy species, which does not begin active vegetation so early in spring as many other Silver Firs; and its young shoots are therefore seldom injured by late frosts.

Economic Value.—The wood is of fair quality; but the tree is merely of interest to arboriculturists.

Soil and Situation.—It thrives best on a soil and in a situation favourable to *Abies grandis*.

Cultivation.—The seed is scarce. When obtainable, it should be sown in a cold frame to prevent loss of seedlings. Trees can also, however, be grown from grafts and layers.

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[1] It is very frequently found in gardens and arboreta under the name of *Abies lasiocarpa*, a point that may perhaps be noted here to avoid any misunderstanding which may arise from the difference in the nomenclature. Some consider this *A. lasiocarpa* as a distinct species from *A. Lowiana;* but the difference seems too unimportant to be specific. The true *lasiocarpa*, also called *subalpina*, differs widely, however, in many respects.

(8) THE NOBLE SILVER FIR, *Abies nobilis* Lindley.

SYNONYMS.—*Pinus nobilis* Douglas ; *Picea nobilis* Loudon ; *Abies nobilis* Henk. and Hochst.

Specific Character.—*Leaves* solitary, rigid, crowded, irregularly 2-rowed, mostly on the upper side of the branches, from $\frac{3}{4}$ of an inch to 2 in. long, linear, falcate, compressed, and turned upwards, flat, rich bluish-green above, and silvery below ; when viewed from a short distance the foliage appears a beautiful mass of rich silvery-green, with shades and tints of violet. *Cones* solitary on the upper part of the top branches, cylindrical, thick, and rather obtuse, from 5 to 8 in. long, and from 2 to 3 in. broad ; at first yellowish-green, but changing to yellowish-purple as they arrive at maturity. *Scales* triangular, with the edges incurved, entire on the margin, and without the bract, $1\frac{1}{4}$ in. long, and about the same broad. *Bracteas* projecting, imbricated backwards, and longer than the scales, jagged round the edges on the exposed part, $\frac{5}{8}$ of an inch long, and with a long and rather broad point or tail in the middle ; *seeds* small, angular, soft, with the wing $1\frac{1}{4}$ in. in length, and $\frac{5}{8}$ in. broad in the widest part (Gordon).

Distribution.—The Noble Silver Fir forms vast forests on the mountains of Northern California, and also grows along the banks of the Columbia River. It was found by Jeffrey on the Shasta Mountains at 6000 to 8000 ft. above sea-level, and was introduced into Britain by Douglas in 1831.

Description.—This is one of the most ornamental of the Silver Fir tribe. It has regular, horizontal, spreading branches, and its foliage is light-green above and silvery below. It attains a height of 150 to 200 ft. with a stem of 3 to $4\frac{1}{2}$ ft. in diameter. The branches are nearly at right angles to the stem, and are densely foliaged with short curved leaves, of a delicate silvery-green on young branches, and of a much darker hue on older ones. The bark of the stem is the colour of cinnamon, that of old branches is purple, and that of young branchlets yellowish-green. It is a hardy tree, of fairly rapid growth here, and our climate seems to suit it well. It is not injured by our coldest winters, which are much less severe than those where it is indigenous. The two largest specimens reported to the Conifer Conference of 1891 had respectively a height of 83 ft., with a girth of 6 ft., and a height of $77\frac{1}{2}$ ft., with a girth of 7 ft. 10 in. at 5 ft. above the ground. The former was growing at Birr Castle (King's County), and the latter at Coul (Ross-shire). In 1903 the Coul tree was 81 ft. by 9 ft. (72 years old), while the next largest specimen reported was 83 ft. by $7\frac{3}{4}$ ft. (Kent, 57 years ; it was 72 ft. by $6\frac{1}{3}$ ft. in 1891).

Economic Value.—The timber of this Fir is soft and white, so that as a timber-tree it must be considered of little interest in Britain, unless it (as also *A. grandis*) could be grown extensively for making wood-pulp.

Soil and Situation.—It is by no means exacting as to soil and situation, but seems to grow better on cool and moist than on dry soil.

Cultivation.—It is hardy, and can easily be raised from seed sown in the usual way without any special protection. Germinable seeds ripen in Britain, and plants can be grown from them, though Californian seed is preferable, as the plants raised from it are stronger and healthier.

(9) NORDMANN'S or THE CRIMEAN SILVER FIR, *Abies Nordmanniana* Spach.

SYNONYMS—*Pinus Nordmannia* Endl. ; *Picea Nordmannia* Loud. ; *Abies Nordmanniana* Lk. and Carr.

Specific Character.—*Leaves* solitary, somewhat 2-rowed, curved upwards, linear, from $\frac{3}{4}$ in. to 1 in. long, with the point emarginate, pale yellowish-green above, channeled below, with a silver glaucous line on each side of the midrib, equal in breadth to the keel, and thickened margins, more or less twisted at the base, and flat. *Branches* dense, and regularly disposed, the lower ones horizontal, the upper ones rising at a more acute angle; young shoots quite smooth and glossy. *Cones* on very short footstalks, erect on the upper side of the branches, from 4½ to 6 in. long, 2½ in. diameter, and egg-shaped, a little blunted at the ends. *Scales* closely adpressed, cup-shaped, very obtuse. *Bracteas* adhering to the narrow base of the scales, but afterwards free and extending beyond the scales, getting wider by degrees from the base outwards, rarely ovate, often cordate, reflexed at the apex, and incumbent on the lower scale, with the point a line and a half long. *Seeds* triangular, soft, and two under each scale. Wing obliquely expanded, membranous, with the inner margin straight, and ripe in September (Gordon).

Distribution.—Nordmann's Fir is abundant on the mountains of the Crimea, and throughout the Alpine regions to the east of the Black Sea. Professor Nordmann of Odessa discovered it on the summit of the Adshar Mountains, towards the sources of the Kur, at an elevation of 6000 ft. It was introduced into Britain in 1845.

Description.[1]—This is decidedly the hardiest species of the Silver Fir tribe that has yet been introduced into this country. It is hardier than the Common Silver Fir, as its young shoots are later of being flushed in spring and are not injured by late frosts. The branches of Nordmann's Fir are regularly disposed and thickly foliaged with dark, glossy, green leaves. It attains a height of 80 to 100 ft. in the Crimea. It has a broad and bushy habit while young. After it has once established itself properly, it grows rapidly, and soon develops into a highly ornamental tree densely clothed with light-green foliage. The two largest specimens reported to the Conifer Conference of 1891 were respectively 70 ft. high, with a girth of 6 ft., and 50 ft. high, with a girth of 10½ ft. at 5 ft. above the ground. The former was growing at Poltalloch (Argyllshire), the latter at Killarney (Co. Kerry). In 1903 the largest specimen reported was 75 ft. by 8¾ ft. (Perth, 48 years; it was 68 ft. by 6½ ft. in 1891).

Economic Value.—In the Crimea the timber is somewhat better in quality, but less per acre in quantity, than that of the Common Silver Fir. But it is seldom found of large size in our woodlands, and is consequently not of sylvicultural importance.

Soil and Situation.—In Britain, it thrives fairly well on almost all kinds of soil that are neither wet nor excessively light and dry. It seems capable of growing wherever Pines, Spruces, and Firs generally are able to grow. Continental experience shows that it makes moderate demands as to soil, being less exacting than the Common Silver Fir, but more so than the Scots Pine. In this respect it resembles the Spruce. Wet soil is unsuitable to it; but it can be grown on dry land, although it thrives best on land that is fresh or moist, whether it be binding or light.

Cultivation.—It requires no special treatment. The seeds and the seedlings can be treated in the same way as those of the Common Silver Fir.

(10) THE PINDROW or UPRIGHT INDIAN SILVER FIR, *Abies Pindrow* Spach.

SYNONYMS—*Pinus Pindrow* Royle; *Taxus Lambertiana* Wallich; *Abies Webbiana var. Pindrow* Brandis.

Specific Character.—*Leaves* solitary, flat, and at first all round the shoots, but finally disposed into two rows on the branchlets horizontally, with the upper surface of the deepest green, almost black when fully matured, and the under one having two faint, white, silvery lines, from 1½ to 2½ in. long, and rather more than one line broad, with

[1] A monograph on this tree will be found in the *Trans. Scot. Arbor. Socy.*, vol. ix., 1879, pp. 94-99.

acutely two-toothed ends. *Branches* in whorls, horizontal, and spreading; branchlets opposite in two rows. *Cones* erect, solitary, 4½ to 6 in. long, and from 3 to 4 in. broad, cylindrical or elongated, flat at the ends, deep purple, smooth on the surface, and growing on the upper side of the top branches; *seeds* soft, angular, full of turpentine, and ripe in October; wing long and ample (Gordon).

Distribution.—This Indian species is abundant on the mountains in Bhutan at 10,000 to 12,000 ft. elevation. In Kamaun, N.W.P., it is found at 7000 to 9000 ft. elevation, where it forms forests of unusual gloom and density. It grows also on the Chur and Kedarkanta Mountains, at 8500 to 12,000 ft. elevation, and on other ranges of similar height. Some of the trees are upwards of 150 ft. high and over 6 ft. in diameter. It was introduced into Britain in 1837.

Description.—Like the Common Silver Fir, it begins active vegetation early in spring, and is consequently liable to injury by late frosts; otherwise it is hardy in our climate. It is a handsome tree, whose stem is densely clothed with short thickly-foliaged branches. The largest specimen reported to the Conifer Conference in 1891 had a height of 43 ft., and a girth of 4 ft. at 5 ft. above the ground. It was growing at Powerscourt (Co. Wicklow). In 1903 the two largest reported were 70 ft. by 8⅔ ft. (Perth, 43 years?) and 50 ft. by 4 ft. 1 in. (Wigton, 47 years; it was 38 ft. by 3 ft. 2 in. in 1891).

Economic Value.—The timber is soft, spongy, and not durable. The tree has only an arboricultural interest.

Soil and Situation.—It grows rapidly on any deep and light loamy soil, that is neither too sandy, too dry, nor too clayey, moist, and cold. It thrives better on a moderately elevated and dry situation than in a low-lying and humid locality; and its growth is better with a cold northern aspect than on a warm southern exposure. It needs protection from the early sun; for when exposed to the direct rays before mid-day, it is apt to get frost-bitten in spring.

Cultivation.—The seed may be sown in a frame, and the young plants need protection for the first two winters. It may also be easily propagated by grafts and layers.

(11) THE SPANISH SILVER FIR, *Abies Pinsapo* Boissier.

SYNONYMS—*Pinus Pinsapo* Endl.; *Picea Pinsapo* Loud.

Specific Character.—*Leaves* solitary, regularly and thickly disposed around the branches, short, ½ an inch long, and placed at right angles to the branchlets, very stiff, sharp-pointed, flat on the upper surface, and with a central rib slightly marked on each side by two furrows, which forms the only and very superficial indication of the two silvery lines so strikingly conspicuous on the under side of the leaves in the Silver Fir tribe. *Branches* regularly in whorls on the main stem, very densely clothed with laterals even to their base, and scarcely extending any wider than those branches nearer, giving the tree a cylindrical rather than a pyramidal shape; the young shoots also have a cylindrical shape on account of the leaves being so thickly placed at right angles all round the stem. *Bark* darker in colour and more scaly than that of the Common Silver Fir. *Cones* erect, in great numbers on the upper part of the top branches towards their extremities, and without any footstalks, oval, cylindrical in form, terminating abruptly at the top, often with a small elevated point, from 4 to 6 in. long, and from 2 to 2½ in. broad. *Bracteas* small, concealed by the scales, and not extending beyond them. *Seeds* angular, soft, and with a membranaceous wing (Gordon).

Distribution.—The Spanish Fir is now found only on the mountains between Ronda and Malaga in Granada, and on the Sierra de Yunquera and the higher parts of the Sierra de la Nieve, at about 3200 to 4000 ft. elevation; but it was formerly much more widely distributed throughout the lower elevations. It abounds on the northern exposures of the higher mountains, reaching up even near to where the snow lies during four or five months of the year. It was introduced into Britain in 1838.

Description.—It attains a height of 70 to 80 ft., with a girth of over 3 ft. It has dense foliage and a branching crown, and is a beautiful tree at all stages of growth. When young it very much resembles the Grecian Fir, but may be easily distinguished from its broader, blunter, and less twisted leaves. It has the close-branched conical habit of growth of the Crimean Fir, but with very distinct foliage; and it contrasts well with this species. It is a hardy species, of moderately quick growth, and by no means exacting as to soil and situation. For the first few years its leading-shoot makes little progress, while the lateral branches grow vigorously, and this gives a rather flat-headed and bushy appearance; but after the root-system has once got fairly established in the soil, the top-shoot rises rapidly, and a tall tree of cylindrical shape soon develops. It has the great merit of being of rapid growth, hardy, and distinctly ornamental. It is particularly beautiful when the male-flowering trees throw out their catkins. The largest Spanish Fir reported to the Conifer Conference of 1891 had a height of 43 ft., and a girth of 4 ft. at 5 ft. above the ground. It was growing at Pampisford (Cambridgeshire). In 1903 a specimen was reported 65 ft. by 9½ ft. (Cambridge, 58 years; it was 62 ft. by 9 ft. in 1891).

A variety of this species (*P. P. var. baborensis*), found growing in the mountainous tracts of Algeria at 4500 to nearly 6000 ft., and often to be met with in the Kabyl country forming forests along with the Mount Atlas Cedar (*Cedrus atlantica*), seems suitable for introduction into Britain. It has been formed into a distinct species, *A. numidica* De Lamroy.

Economic Value.—The timber is of about the same quality as that of the Common Silver Fir, and is full of resin, which indicates considerable durability. But the tree has no claims to anything more than a purely arboricultural interest.

Soil and Situation.—It thrives on most soil found suitable to the Common Silver Fir; but it requires a sheltered situation, neither too elevated nor too exposed to wind.

Continental experience shows that a considerable amount of warmth is requisite for the Pinsapo Fir before it can produce seed of germinative capacity. Thus, in Southern Germany it cannot be relied on to ripen its cones, for which reproductive effort a very considerable amount of summer warmth is required, as for example in the Adriatic basin; and even the mildest parts of England do not offer such a climate.

Cultivation.—Seeds of this species are imported from Spain, and generally sown in a cold frame to protect the seedlings for the first and second winters; but the seedlings are freely exposed during the summer months. The young plants seem hardy, and are not specially liable to be injured by our winter frost.

(12) WEBB'S INDIAN SILVER FIR, *Abies Webbiana* Lindley.

SYNONYMS—*Pinus Webbiana* Wallich; *Picea Webbiana* Loudon.

Specific Character.—*Leaves* solitary, at first scattered all round the shoots, but finally more or less arranged in two rows laterally, from 1 to 2 in. long, linear, flat, leathery, bidented on the end, of a dark and glossy green above, and furnished with two broad white bands below. *Branches* in regular whorls, horizontal and spreading; branchlets opposite, 2-rowed, and stout. *Buds* oval, covered with brown scales, and resinous. *Cones* solitary, erect, and of a rich purple colour, from 6 to 7 in. long, and about 2½ in. broad, cylindrical, blunt-ended, full of resinous matter, and growing on short stout footstalks on the upper surface of the top branches. *Seeds* soft, oblong, or angular. Wing thin, broad, and somewhat obovate (Gordon).

Distribution.—Webb's Fir grows to about 70 or 80 ft. high on the Himalayan Mountains, where its lowest limit on the southern slopes is about 10,000 ft. Griffith rarely found it below 9500 ft. in Bhutan, but it forms large forests at 12,000 to 13,000 ft.

elevation. Hooker found it in Sikkim measuring 30 ft. in girth. It also forms extensive forests on the northern side of the Shatul Pass, but not on the south face. It was introduced into Britain in 1822.

Description.—It is one of the prettiest of the Silver Firs. It has more of the silvery tinge on the lower side of the leaves than any other species, and may thus easily be distinguished. The two largest specimens reported to the Conifer Conference of 1891 were respectively 52 ft. high, with a girth of 6¼ ft., and 51 ft. high, with a girth of 8 ft. at 5 ft. above the ground. The former was growing at Courtown, in Wexford; and the latter, at Howick Hall in Northumberland, girthed 8½ ft. in 1903 (62 years old), but has now lost its top.

Economic Value.—The timber is soft and inferior. The tree has merely arboricultural interest.

Soil and Situation.—As for the Pindrow Fir.

Cultivation.—The seeds are generally sown in a cold frame to protect the young seedlings during the first two winters. It may easily be grown from grafts or layers. It is hardy after once it outgrows the heavy damp layers of air; but young shoots are apt to be bitten by frost in spring and autumn.

The largest among other ornamental Silver Firs reported on in 1903 are two *A. magnifica*, 40 ft. by 5 ft. (Lincoln, 36 years) and 50 ft. by 3½ ft. (Perth, 30 years), and one *A. concolor*, 87 ft. by 11 ft. 7 in. (Kent, 42 years; it was 64 ft. by 8 ft. 7 in. in 1891).

6. THE LARCH, *Larix* Miller
(Linnæan System, Monœcia Monadelphia).

Generic Character.—Trees with long shoots and scattered foliage, or with short spurs and leaves in tufts; the *leaves* in both cases linear, deciduous, soft. *Male flowers* in short spikes, anthers apiculate, 2-lobed, dehiscing transversely. *Pollen* grains very large, globose. *Cone-scales* woody, persistent. *Seed* without resin-canals. Wing of seed oblong, acute. *Cotyledons* 6-8, 3-cornered or flat, entire. Primary leaves entire (Masters).

Up to the present 9 species of Larch are known. All of these are deciduous trees, and some attain large dimensions. They are indigenous to all the northern portions of Europe, Asia, and North America, and to the mountainous regions of Central Europe and Asia, extending eastwards to Japan. Only four species are worthy of sylvicultural attention, the Common, the Japanese, the Kurile, and the Siberian Larch.

(1) THE COMMON LARCH, *Larix europæa* DC.

Synonyms—*Pinus Larix* L.; *Larix excelsa* Link.; *L. decidua* Miller; *Abies Larix* Poir.; *Larix pyramidalis* Salisbury.

Specific Character.—*Leaves* in wisps, tufts, or bundles, many together round a central bud (short shoot), but singly on young plants and the leading-shoots (long shoots),[1] deciduous, linear, soft, blunt or rounded at the points, spreading, slightly recurved, and of a beautiful bright and light green. *Cones* of a longish oval shape, erect, of a brown colour, about 1 in. in length, ripen late in the autumn, and remain for a long time on the trees. *Scales* persistent or not

[1] The *bark of the shoots* is *ash-grey;* while in the Japanese Larch it is *reddish-brown,* and in the Kurile Larch *deep blue-red.*

falling off, roundish, streaked, and slightly waved on the margins. *Bracteas* generally longer than the scales, particularly towards the base of the cones. *Seeds* small, of an irregular oval form, with a broad wing. *Seed-leaves* from 5 to 7 (Gordon).

Distribution.—The Common Larch is only indigenous to the hilly regions throughout Central Europe, where it forms large forests on the Alps. Its proper region is at an elevation of 3000 to 6000 ft., although it is found much dwarfed up to 7000 ft. It also occurs in Tyrol and Hungary on the Carpathian Mountains. It is not indigenous to any other part of Germany than the Bavarian Alps, though it has been largely cultivated in most parts of the German empire. It was introduced into England in 1629, into the Lowlands of Scotland in 1725, and into the Perthshire Highlands in 1727.

The natural distribution of the Larch can now hardly be determined, as it has been so much cultivated artificially without any exact record having been kept. Its northern limit seems to be on the outliers of the Carpathians at about 50° of latitude; while its southern, and at the same time its western, limit is situated on the Dauphiny Alps at about 44½°. As regards locality, its northern sphere of indigenous growth is probably circumscribed by an irregular line across the Jura range and the Central and Bavarian Alps towards the northern Carpathians, whence it trends south-east to Kronstadt in Transylvania, which also probably forms its eastern limit. The southern limit of growth runs irregularly along the southern slopes of the Alps, skirting Croatia and Southern Hungary (Willkomm).

As a knowledge of the climatic conditions under which the Larch can grow in a healthy normal condition is of practical importance for Forestry in Britain, the following summary of Willkomm's investigations on this point may be quoted (*Forstliche Flora*, 2nd edit., 1887, p. 153):—

The essential climatic conditions for the normal development of the Larch appear to consist of (1) a mean annual temperature not below 1° nor above 8° C. (33·8° and 46·4° Fahr.); (2) a non-vegetative period of winter rest extending over at least four months; (3) a short spring, with rapid transition from spring to summer (*i.e.*, a rapid rise in temperature at the time of the development of the foliage and flowers); (4) a damp atmosphere in spring and early summer; (5) a constant and equable warm summer for three months; (6) a situation protected against cold and dry winds; (7) undisputed enjoyment of light and air, and consequently a large growing-space; and, finally, (8) a moderately moist, light, deep, limy or argillaceous soil.

Description.—The Larch is a graceful deciduous tree of a conical habit of growth. In favourable situations it often attains 80 to 100 ft. in height and 3 to 4 ft. in diameter. It generally forms a very straight bole; and where it has sufficient growing-space, graceful pendent branches clothe the stem from top to bottom. The two largest specimens reported to the Conifer Conference of 1891 were respectively 100 ft. high and 10 ft. in girth, and 80 ft. high and 11 ft. in girth at 5 ft. from the ground. The former was growing at Rossdhu (Dumbarton), and the latter at Howell (Worcester).

The trees considered to be the two oldest Larches north of the Forth (1727) are in the grounds of the dower-house of the Athole family at Dunkeld. They formed part of some sent to the Duke of Athole from the Tyrol by Mr Menzies of Culdares. Treated first as tender exotics, they were grown in the greenhouse; but becoming sickly, they were cast out on a litter-heap, where two of them took root and began to recover in the cooler air. On this being noticed, they were planted in their present places, near the west end of

Dunkeld Cathedral, where they form very interesting arboricultural objects. The Duke was so well pleased with the vigour and beauty of the new importation, and with the prospect of profit it afforded, that he planted about 25,000 acres with Larch before he died in 1764. Over-sanguine expectations were formed about these plantations; but they were of course never realised, owing mainly to the mistake made in growing the Larch pure in place of only in mixed woods.

Economic Value.—It is decidedly one of the most valuable trees ever introduced into this country, both with respect to the rapidity of its growth and the value of its durable timber. Its wood is far tougher, stronger, and more durable than any other conifer, except, perhaps, the Yew. Even at an early age it is hard, tough, and durable, and is therefore suitable for fencing when still of small size. In most rural districts it fetches 1s. a cubic foot (while Douglas Fir is 9d. and Scots Pine 6d.) It will probably always remain one of the most profitable trees to plant in naturally well-drained land in Britain, its chief rival in this respect being the Douglas Fir. It is in constant demand, and the only sources from which large supplies of Larch (European and Siberian) timber are in future likely to compete with good home-grown wood is from the Northern Russian districts. Indigenous to the mountains of Central Europe, it has proved itself as hardy as the Scots Pine throughout all the hilly tracts in Great Britain and Ireland; but it is certainly less accommodating as to soil and situation, because it will only thrive on land having good natural drainage. Its best growth and dimensions, as well as the finest quality of its timber, are attained when it is grown in admixture with other trees; and it is perhaps when growing along with Beech that it reaches its finest development. In Ireland it is often to be found of excellent growth in old Oak coppice-woods that were converted into mixed highwoods from thirty to sixty years ago, by means of interplanting Larch and Pine among the Oak-stools at the last time of coppicing.

Larch is extensively used for all purposes in our rural economy. Its durability makes it specially adapted for mining operations, and such large quantities of it are annually used that in some mining districts the demand for small pit-wood often far exceeds the supply. For railway sleepers there is also considerable demand, as it is preferable to creosoted Pine, when it can be had at anything like the same cost, because it lasts longer than any other kind of home-grown wood when under the wear and tear of traffic and the decomposing influence of damp, warmth, and saprophytic fungi.

For interior work the builder prefers the softer though less durable wood of Pine, Spruce, and Silver Fir.

Larch is the one wood for which a ready sale can always be found in any part of the United Kingdom. Most of what is grown in Ireland is exported to Cardiff or Liverpool for the coal-mining districts; and of course the local value of timber varies with the cost of transport.

On the Continent it is used for similar purposes as Scots Pine; but, as it is better and more durable, it of course is higher in price. Its wood is the heaviest of any of the European Conifers grown as crops of timber, though, as its average sp. gr. is only 0·81 when green and 0·59 when seasoned, it is floatable immediately after felling. When grown at high elevations, and with well-developed and resinous heartwood, it ranks along with (and often above) Oak as the most durable of European woods; and in respect to general durability is only approached by Scots and Black Pines (Austrian and Corscian), Acacia (*Robinia*), and Sweet-Chestnut. Yet at the same time the wood is soft and elastic.

Soil and Situation.—The three main physical essentials, apart from purely climatic requirements, for the vigorous growth of Larch seem to be (1) a deep light soil, to permit the deep-reaching root-system to develop without hindrance; (2) good natural drainage, both in the soil and the subsoil; and (3) a sufficiency of individual growing-space, so that each tree-top may have at least its minimum requirements as to light satisfied. But even with all these three first essential demands supplied, crops of this valuable timber-tree are often seriously damaged, or even absolutely and entirely ruined, by neglect of what seems to be a fourth essential for the production of healthy Larch timber in this country—namely, (4) the cultivation of Larch merely in single stems or small family groups interspersed among other trees. It only occurs thus, and never forming large pure woods, in its native home; and it will not thrive for any length of time where forced artificially to grow gregariously, as bitter experience of the fungous canker-disease (due to *Peziza Willkommii*: see vol. ii., Part IV., *Protection of Woodlands*) has shown in every part of the United Kingdom. It thrives perhaps best of all on a light, stony, and moderately fresh soil; but when the land is inclined to wetness in soil or subsoil, even though the young poles may grow vigorously, the trees soon get spongy in the butt, and rot prematurely. On gravelly soil Larch is often extremely liable to red-rot.

None of our forest-trees is hardier than Larch: it will grow at as high an altitude as Scots Pine, though on high-lying sites with poor soil the Scots Pine is usually the better tree to plant for profit and shelter.

Continental experience shows that the Larch grows best on limy soil, and also does well on loamy or argillaceous sand, while dry, wet, or very binding land is under all circumstances decidedly unfavourable for its healthy and normal development. Neither tenacious and binding clay or lime, nor poor soil, nor land that is between moist and wet, is favourable to its attaining maturity normally; and in suppressing rank growth of heath and heather, Spruce and Scots Pine have been found more satisfactory than Larch. But where grazing considerations are simultaneously taken into account, the Larch has better claims to attention than any other kind of forest-tree.

Cultivation.—Larch is raised from seed, either of home-growth or else obtained from abroad. Differences of opinion exist as to which is preferable, but it seems only reasonable to expect that fresh seed from the Alps will, when it can be relied on to be of first-class quality, give at least as good plants as the very best that can be produced here, and will probably be considerably better than that collected from trees of weakened vitality (whether from unsuitable soil and situation, or from infection with the canker fungus). The seed should be sown on well-prepared soil, and only lightly covered with earth.

The seedlings may be transplanted into the nursery-rows when one year old, and put at 4 in. apart with 6 in. between the rows; and after standing there for one year, or for two years if stout plants are wanted, may be planted out in the open. They are hardy, establish themselves readily, and soon grow rapidly. They are therefore often, like the Birch, used as "nurses" for slow-growing and less hardy kinds of trees.

Sylvicultural Characteristics.—In Scotland the Larch has to grow under climatic conditions which vary greatly from those obtaining in the Alpine tracts where it is indigenous. On the northern slopes of the Alps, where it occurs most extensively, there is practically no long spring or autumn, and anything like the commencement of active vegetation so early as March (as often takes place in the warmer parts of Britain) is inimical to its healthy development. On the northern slopes of the Alps everything remains frost-bound till the middle or end of April. But by the middle of May it is practically summer-like in temperature; all the forest-trees (Beech, Spruce, Larch, Pine) are in leaf, and heath and forget-me-not are in full flower. The transit from summer to winter is equally rapid, and there is no abnormal prolongation of autumnal activity. The longer periods of spring and autumn vegetation induced by our milder insular climate certainly quicken the growth of the Larch; but, judging from the practical results throughout Britain, they are decidedly prejudicial to its value as a timber-crop. They weaken the inherent constitutional power of the Larch in resisting the attacks of noxious insects (like the aphis, *Chermes Laricis;* and the mining-moth, *Coleophora laricella*) and of the canker fungus (*Peziza Willkommii*). The latter has followed the tree from the Alps, and in this milder climate is able to fructify more abundantly, while it also finds the Larch less able to resist the infecting power of the germs, so much more numerously developed here than in the true home of the tree.

This is one of the two chief reasons why the Larch has not permanently done so well as a forest-tree in our islands as it might have done. The other reason is that it has been grown far too much in pure woods, or forming too large a numerical proportion of the crop, because when growing spontaneously in the regions to which it is indigenous it is found only as individual trees or in small family groups interspersed among other trees, and *never* forming pure woods or the numerical majority in mixed woods. So far as climate is concerned, the colder northern slopes of hills suit it better than warm southern hillsides, because the north side of a hill approximates nearer to the Alpine conditions as regards the awakening of vegetation in spring, its cessation in autumn, and the long cold period of complete rest in winter.

Its root-system is deep-reaching like that of the Scots Pine and the Oak, hence depth of soil is essential. But its leading characteristic as a forest-tree is its intolerance of shade either from above or from the side. It is the most *light-demanding* of our forest-trees, not even excepting the Birch. It is therefore not naturally adapted for forming pure forests, as has so generally been the mistake made throughout Britain. When it begins to make unmistakable demands for larger growing-space between the twentieth to thirtieth year of age, it is no longer able to protect the productivity of the soil.

The best way to grow it is undoubtedly to mix it with shade-bearing trees like Spruce, Douglas Fir, Silver Fir, or Beech. In the latter case it will usually be of forward growth, except with the Douglas Fir; but its light side-shadow should not interfere much with the growth of the other trees. In woods of Spruce, the Larch is generally caught up in growth about the thirtieth year, and in woods of Silver Fir about the fiftieth year. Whenever this is likely to take place, the other tree must either be thinned out, or else the Larch must be cut and utilised, as otherwise it will become suppressed.

As a standard over coppice it does very well, and soon grows into timber of valuable dimensions. In this case a little money spent in pruning the lower branches at each time of clearing the coppice will give a very profitable return in keeping the bole free from large knots.

Owing to the strong demand of the seedlings for light, Larch-woods cannot be easily or conveniently regenerated naturally. And in the formation or the artificial reproduction of woods, planting is preferable to sowing.

(2) THE JAPANESE LARCH, *Larix leptolepis* Gordon.

Specific Character.—*Leaves* somewhat over ½ in. long, blue-green. *Young shoots* reddish-brown. *Cones* from ¾ to 1¼ in. long, ruddy light-brown. *Bracteas* soft, and slightly bent back along the edge, about twice as long as the scales. *Seed-leaves* 4-6, bent slightly downwards, are immediately followed by the ordinary leaves of the long shoots.

Distribution.—It is indigenous to the central part of Japan, and attains its finest development in the island of Nippon between 34-41°, and in a cold and comparatively dry climate at 1600 to 2400 ft. elevation. It was introduced into Europe in 1861.

Description.—This tree is very much like the Common Larch, but can easily be distinguished by its leading-shoots being reddish, and not ash-grey as in the European species, or blue as in the Kurile Larch. It is also of more rigid habit and more rapid growth when young, plants eight years old being often between 16 and 17 ft. high; but later on the Common Larch overtakes it. It forms a clean, straight stem, and attains a height of 100 ft. It is a very hardy species, and is (as yet) in Britain much less liable than the Common Larch to be attacked by the Larch aphis, the mining-moth, and the canker fungus, though unfortunately it is not altogether immune from injury. It is hardy alike with regard to frost, heat, and drought, and has a strong recuperative power of healing wounds and replacing its leader. It is in some ways even more ornamental than the Common Larch as a park tree, as its blue-green foliage turns golden-yellow in autumn. The oldest and largest specimen reported in 1903 was 41½ ft. high and 3 ft. 3½ in. in girth at 4½ ft. up (Tortworth, Gloucester; about 41 years old).

Soil and Situation.—It thrives best, like the Common Larch, on deep, sandy-loamy soil, and in naturally well-drained, airy situations.

Economic Value.—The timber has very much the same qualities as Common Larch, and the tree would probably be planted more extensively in woodlands than has yet been the case, if plants were cheaper. At present they are about 50 per cent dearer than European Larch.

Cultivation.—As detailed for the Common Larch; but as the seedlings and young transplants grow more rapidly, they can often be sent out of the nursery a year earlier.

(3) THE KURILE LARCH, *Larix curilensis* Mayr.

Specific Character.—*Leaves* dark-green, 1 to nearly 2 in. long, the topmost 5 to 6 in. long, stiff, hard, bent back in sickle-shape. *Shoots* deep blue-red, slightly hairy, and with a bloom. *Female flowers* with blue-red bracteas. *Cones* $\frac{3}{4}$ to 1 in. long, remaining dark-red till ripening; cone-spindle with orange hairs. *Seed-leaves* usually 5, narrow, hard, and bent upwards (thus differing from *L. leptolepis*); they are followed by 5 blue-green leaves of half their length and twice their breadth, and after eight to ten weeks' growth a shining brown bud is formed. (Klein, *Forstbotanik.*)

Distribution.—This tree is a native of the Kurile Islands in the extreme N.E. of Japan, at an elevation of about 1500 to 2500 ft. It was introduced into Europe in 1889 by Mayr.

Description.—Where indigenous it reaches a height of 80 to 85 ft., but is not a common tree. It is quite hardy, and is exceedingly rapid in growth when young, outstripping even the Common and the Japanese Larch. It flushes its foliage earlier than these, but late frosts do not injure it.

Economic Value.—Being smaller when mature, it is probably of less value than either of the other two kinds of Larch. But as it does well during drought, it may perhaps be found useful for growing in mixture with Banks' Pine in very dry situations.

Cultivation.—As for the Japanese Larch.

(4) THE SIBERIAN LARCH, *Larix siberica* Ledebour.

Specific Character.—*Leaves* much longer ($1\frac{1}{4}$ to 2 in.) than on Common Larch, and foliage altogether richer. *Female flowers* pale-green. *Cones* about $1\frac{1}{2}$ in. long, and, even when ripe, with felt-like hairs on the scales. *Scales* remain tightly closed, with inward-curved edges, till the seed is scattered (Klein).

Distribution.—It is widely distributed through Northern Russia and Siberia, and was introduced from Archangel by the Duke of Atholl in 1806.

Description.—It is very much like the Common Larch both in appearance and rate of growth, though perhaps rather slower at first; but it forms a straighter stem. It is more suited for a marked Continental than a milder climate, because it starts growing early in spring, and is liable to damage from late frosts.

Soil and Situation.—It is an accommodative species; but, like the Common Larch, does best on a deep soil and in a well-drained situation.

Economic Value.—The timber is much the same as that of the Common Larch, and the tree might be more extensively planted on cold northern aspects if the plants were not so much dearer than those of the latter.

Cultivation.—As detailed for the Common Larch.

7. THE CEDAR, *Cedrus* Lk. (Linnæan System, Monœcia Monadelphia).

Character of the Genus.—Trees with long shoots and scattered *leaves*, or with short "spurs" and tufted leaves, the latter in all cases linear and persistent. *Stamens* in catkins; anther-lobes 2, crested; pollen-cells winged. *Cone-scales* overlapping, ultimately falling, but leaving no central axis. *Scales* much larger than the bracts. Wing of seed truncate, very large. *Seed* with resin-canals. *Cotyledons* leafy, 8-9, entire, 3-sided (Masters).

The Cedars are evergreen and highly ornamental trees. They are indigenous to Mount Lebanon, the north of India, and the Barbary and Atlas Mountains in Northern Africa. They are quite hardy in Britain.

Only three species are known of this genus—viz., the Cedar of Lebanon, the

Atlas or Algerian Cedar common to Asia Minor and Northern Africa, and the Deodar of the Himalayas. Both of these latter species are, however, regarded by Hooker and Grisebach as probably merely climatic varieties of the Cedar of Lebanon.

(1) THE CEDAR OF LEBANON, *Cedrus Libani* Loudon.

SYNONYMS—*Pinus Cedrus* L.; *Larix Cedrus* Miller; *Abies Cedrus* Poir. and Lindley; *C. patula* Koch.

Specific Character.—*Leaves* simple, very dense, in alternate tufts, of about thirty in number, evergreen, rigid, partially 4-sided or cylindrical, tapering to the point, straight, 1 in. long, sharp-pointed, and of a dark grass-green colour. *Branches* horizontal, and with the branchlets disposed in a flat fan-like manner on them, very numerous, and thickly set with leaves. *Cones* erect, ovate, flattened at the ends, and depressed, 4 to 5 in. long and 2½ in. wide, with rather a long footstalk, of a greyish-brown colour, and persistent, remaining firmly attached for years to the branches. The cones require two years to ripen, and exude a large quantity of resinous matter while growing (Gordon).

Distribution.—This well-known species is a native of Mount Lebanon in Syria, and was introduced into Scotland about the year 1683, when specimens were planted in the Botanic Garden, Edinburgh. Besides the ancient Cedar forests of Lebanon, frequently mentioned in the Old Testament, which are now limited to a few trees, this tree occurs of spontaneous growth throughout the Taurus range in Asia Minor, where it still forms extensive woods, and also on the Atlas Mountains in Northern Africa at 4000 to 6400 ft. elevation.

Description.[1]—As an ornamental tree, an old Cedar of Lebanon, with its massive widespreading branches, is second to none of the Conifers introduced into Britain. It throws out great strong lateral branches, and even after it has completed its full growth in height, these continue to spread until the full-grown tree presents a broad, rounded, and almost flat head. If confined among other trees, it rises with an upright stem like other Conifers; but it has no sylvicultural value in Britain.

Where indigenous, it is said to grow to a height of 120 ft.; but here it does not exceed 80 to 100 ft. when full grown. In 1860 Hooker found the remains of the ancient Cedar forests of Lebanon to consist of nine groups of Cedars, amounting to about 400 trees in all, whose ages he estimated as varying from 100 to 2500 years. The two largest specimens reported to the Conifer Conference in 1891 were respectively 90 ft. high, with 9 ft. 10 in. in girth, and 82 ft. high, with 16 ft. 2 in. in girth at 5 ft. from the ground. The former was growing at Methven (Perth), and the latter at Bretby (Derbyshire). In 1903 the two largest reported were 82 ft. by 16 ft. 2 in. (Derby, 215 years) and 109 ft. by 12 ft. 2 in. (Bucks, 111 years).

On the Dropmore estate in Bucks there is an avenue of 170 Cedars of Lebanon, planted ninety years ago, that now average over 75 ft. in height and 8 ft. in girth; and though the roadway between the lines is about 50 ft. across, the heads of the trees (which are 25 ft. apart) on each side have closed up so as to shut out the sun's rays.

Economic Value.—Although very durable where indigenous, the timber grown in Britain is soft and inferior, and not nearly so good as that of many other Conifers. But in any case, this tree is of much too slow a rate of growth here for a timber-crop. The only utility of its wood is for decorative purposes, for which its pale pink colour and its faint sweet fragrance render it very suitable.

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[1] A monograph *On the Cedar of Lebanon* will be found in the *Trans. Roy. Scot. Arbor. Socy.*, vol. xiii. part ii., 1892, pp. 200-219.

Soil and Situation.—It is a very hardy tree, in every way suitable to our climate. It is accommodative with regard to soil, if only this be dry and deep, with a permeable subsoil. It will grow well on most land suitable for forest-trees. It seldom flowers before it is from fifty to sixty years old, and does not begin to bear seed till it has attained a considerable age and size. It flowers in September or October, and the seed takes two years to ripen. When the cones are ripe, they remain attached to the branches for several years, with all their seeds in them. The cones should be gathered in spring, and the seeds extracted immediately after; or if the cones be procured from the Levant, they may be laid past in a dry airy loft till the time of sowing has arrived. The seeds should be sown in April about an inch apart, on light, well-prepared ground, and should be covered with not more than five-eighths of an inch of earth. The seedlings will come up in about five or six weeks after sowing, and should be transplanted into nursery-rows when one year old, and allowed to stand there till they reach the size desired. They are sometimes put in pots when one year old, and changed into larger pots as they require more root-room; and in this way they can be planted out at any convenient time of the year.

(2) THE DEODAR or INDIAN CEDAR, *Cedrus Deodara* Loudon.

SYNONYMS—*Pinus Deodara* Roxburgh; *Abies Deodara* Lindley.

Specific Character.—*Leaves* evergreen, somewhat 4-sided, needle-shaped, acute-pointed, pungent, very glaucous, and from 1 to 2 in. long; those on the principal and lateral branches are collected in tufts or close bundles of from thirty to sixty in number, on very short and numerous branchlets, while those on the young shoots are solitary, alternate, and scattered along the twigs; when young very glaucous, but getting much greener as they get older. *Branches* very stout, irregularly placed along the stem, much divided, horizontal, and quite flat, the lower ones being more or less deflected and hanging close to the ground. The general aspect of the tree when young is drooping and very graceful; but as it grows older and larger the branches assume a stiff, flat, and solemn appearance, like that of the Cedar of Lebanon. It *flowers* in September, and the *seeds* are ripe in October or November of the following year, or in about thirteen months. The *male catkins*, though solitary, are very numerous, erect, 2 to 3 in. long, and are at first oval, but gradually become cylindrical; the majority of these and the *female flowers* are produced on separate trees. But a considerable number of these trees also produce both male and female flowers on the same individual. In about a month after the Deodar has flowered, the young cones, covered with a bluish bloom, appear. They are cylindrical in form, without any footstalks, and solitary on the top of the little tufts of leaves. *Cones* erect, solitary on the upper side of the stout top branches, ovate, obtuse, or nearly cylindrical, from 3 to 5 in. long, and 2½ in. wide, flat, slightly depressed at both ends, and very much resembling, in general appearance, those of the Cedar of Lebanon; but they are of a rusty-brown colour, and when the seeds are ripe they break up and fall to pieces, shedding both scales and seeds on the ground (Gordon).

Distribution.—The Deodar occurs extensively in pure and mixed forests on the Himalayas at 4000 to 12,000 ft. elevation. Up to about 6500 ft. its chief associate is the Long-leaved Indian Pine; while from about 8000 or 9000 ft. upwards its principal associates are the Himalayan Spruce and the Pindrow Fir. It grows on all the higher mountains from Nepal to Cashmere; and Griffith found it of great size in vast forests towards Kafiristan, at 6000 to 10,000 ft. elevation. In 1830 Madden found one tree of 36 ft. girth near the base, and several from 150 to 200 ft. high and not less than 30 ft. in girth. In the Indian Forest School Museum at Dehra Dún, N.W.P., there is a section of a stem 10 ft. in diameter and showing 2000 annual rings. The Deodar was introduced into Britain in 1822.

Description.—It is easily distinguishable from the Cedar of Lebanon by the drooping habit of its branches, especially while young, and by its lighter appearance generally, whereas the Cedar of Lebanon is dark-green, strong, firm, and even while young spreads its branches horizontally. With age, however, its branches becomes stiff and flat, and it gradually approximates more to the character and outline of the Cedar of Lebanon, although on the whole it is not quite so ornamental. One of its characteristic peculiarities is that the top of the tree seems to be always bent down, often at about right angles to the stem. The two largest specimens reported to the Conifer Conference in 1891 were respectively 70 ft. high, with a girth of 7½ ft., and 46 ft. high, with a girth of 10½ ft. at 5 ft. above the ground. The former was growing at Studley Royal (Yorkshire), and the latter at Coollatin (Co. Wicklow). In 1903 the two largest reported were 102 ft. by 8 ft. 5 in. (Bucks, 63 years) and 73 ft. by 10¾ ft. (Kent, 62 years; it was 60 ft. by 9½ ft. in 1891).

Economic Value.—The timber is one of the best in Northern India. Owing to the presence of an aromatic essential oil, the wood is not attacked by insects, while it is also immune from fungous decay. This makes it one of the best woods for sleepers in the destructive climate of India. It is also largely used for house-building, but the main drawback to it then is that during hot weather it emits a strong oily smell, sometimes unpleasantly overpowering during excessive heat. It is even-grained, easily worked, takes a good polish, and does not shrink, so that it might be suitable for furniture or decorative interior work here. But it is only of arboricultural interest. Experiments in Central Germany show that it is of rapid growth, and produces good wood; but it has not proved itself a sufficiently hardy species for cultivation in the woodlands.

Soil and Situation.—In Britain it grows on soil of every description from light sand to stiffish clay. But for it to thrive well, both the soil and the subsoil should be dry and permeable. On shallow, cold, retentive soil, and wherever there is a stiff moist subsoil, it sickens and soon dies. It likes plenty of light and air, and can do well at moderate elevations; but it gets wind-bent and stunted if exposed to high winds.

Cultivation.—As for the Cedar of Lebanon.

(3) THE MOUNT-ATLAS or ALGERIAN CEDAR,
Cedrus atlantica Manetti.

SYNONYMS—*Pinus atlantica* Endl.; *Abies atlantica* Lindl.; *Cedrus argentea* Hort.

Specific Character.—*Leaves* in tufts, or singly, on the young shoots, stiff, needle-shaped, cylindrical, or flattened on the upper side, sharp-pointed, and straight; evergreen, with a silvery appearance, and shorter and denser than those of the Cedar of Lebanon; very irregular in length in the fascicles, varying from ½ to ¾ in., longer on the leading-shoots, and with a furrow running along the whole length of the leaf. *Branches* rather slender, less rigid, and covered with scattered bundles of leaves, mostly opposite, but sometimes very irregularly placed. *Cones* ovate, flattened, or rather depressed at the ends, from 2½ to 3 in. long, erect on the upper side of the external branches, of a shining light-brown colour, and full of resinous matter (Gordon).

Distribution.—This tree is abundant on the mountains in Barbary, and especially on the Atlas range, at 7000 to 9000 ft. elevation. It was introduced into Britain in 1843.

Description.—When young the Atlas Cedar resembles the Cedar of Lebanon very closely, but it is of a more upright habit, grows more rapidly, and has fewer branches; while it differs from the Deodar in never assuming the pendulous habit characteristic of the latter. It is as hardy as the Deodar, and though tardy in sending out shoots in spring, is of much quicker growth than the Cedar of Lebanon, because at five years of age it will be at least 2½ ft. high, while the latter will not be over 18 in. If exposed to high winds it grows slowly, and, like the Deodar, becomes stunted. The two largest specimens reported to the Conifer Conference of 1891 were respectively 66 ft. high, with a girth of 5 ft. 10 in., and 48 ft. high, with a girth of 9 ft. at 5 ft. above the ground. The former was growing at Mulgrave (Yorkshire), and the latter at Brahan (Ross-shire). In 1903 the largest specimen reported was 75 ft. by 8 ft. 2 in. (York, 72 years; it was 70 ft. by 7½ ft. in 1891).

Economic Value.—The wood is not so durable as Deodar, and in any case it can only have an arboricultural interest in Britain.

Soil and Situation.—Its requirements as to soil and situation correspond very closely with those of the Deodar. It is not only quite hardy climatically, but is also accommodative as to soil, unless the latter be wet or heavy and stiff. It does well on limy soil.

Cultivation.—This species can be raised from the seed produced in warm seasons in England in the same way as the Cedar of Lebanon. Like the Corsican Pine, it does not stand transplanting well.

III. *CUPRESSINEÆ* Rich.

The tribe **Cupressineæ** is divided into six genera, in all of which the foliage consists of scale-like sessile leaves, usually opposite or ranged in whorls, and less frequently alternating; when scale-like, they are imbricate or ranged one above another like overlapping tiles on a roof. The cones usually have thin woody scales; but sometimes the seeds are enclosed in a sarcous fleshy mass (in the Junipers). The Common Juniper is the only member of the tribe indigenous to the British Isles.

1. THE TRUE CYPRESS, *Cupressus*
(Linnæan System, Monœcia Monadelphia).

Generic Character.—True Cypresses are known by their scale-like adpressed adult leaves, never in two ranks, monœcious *flowers*, male flowers spiked, anthers four or more, crested, pollen globose; *cones* globular or oblong, woody, ripening in the second year, with peltate *scales*, and numerous *seeds* to each scale. *Cotyledons* 2, leafy, longer than the primary leaves, which are opposite, or in whorls of 4 (Masters).

The True Cypress sub-tribe consists altogether of large trees or bushes indigenous to Southern Europe, North America, California, Mexico, Guatemala, China, and India. In this sub-tribe the leaves along the branchlets are mere scales, closely overlapping each other, and generally in four rows, with the branches always scattered along the stem, and the buds not scaly. The cones are always small, more or less globular, and composed of 6 to 10 woody scales, each having a projecting point in the centre; and when the seeds are ripe the scales become dry and separate. All the species exude resin, but yield no turpentine.

(1) THE COMMON UPRIGHT or ITALIAN CYPRESS,
Cupressus sempervirens L.

Synonyms—*Cupressus fastigiata* DC.; *C. sempervirens stricta* Ait. and Loud.

Specific Character. — *Leaves* imbricated, in four rows, small, deep, glossy green, closely pressed to the stem, convex, blunt, or pointed on young plants, and persistent. *Cones* large, globular, 1 in. or more in diameter, with numerous large angular *scales*, slightly convex, and mucronate, or tipped with a hard point, in the centre, which become woody and separate when ripe. *Seeds* numerous under each scale, yellowish-brown, irregularly angular, and covered with a thin membranaceous skin (Gordon).

Distribution.—The Common Cypress is indigenous to Greece, Asia Minor, and Persia, but is now acclimatised throughout Southern Europe. It is cultivated all along the Mediterranean. It was introduced into Britain in 1548.

Probably only a denizen from Eastern lands, and not really indigenous to Europe, the Cypress has been very extensively cultivated throughout Southern Europe. In Southern France and Italy it forms, along with the Australian Blue Gum (*Eucalyptus globulus*) and the Pepper-tree (*Schinus molle*), one of the most characteristic arboreal additions to the flora of the Riviera. Its dark-green foliage contrasts well with the grey-green of the Olive groves. Being of sombre aspect like our Yew, it has been largely planted in churchyards and cemeteries as a symbol of mourning.

At Sabioncello, in Dalmatia, there is a small Cypress forest, formed probably from seed shed by trees originally planted, which now reproduces itself naturally (Willkomm).

Description.—In warm climates the Common Cypress grows to a height of from 70 to 90 ft., with a stem of 12 to 18 in. in diameter; but in Britain it is seldom found above 40 ft. high. It is a beautiful, though sombre and sad-looking, evergreen tree, very much like a larger kind of Yew, and growing, like the Lombardy Poplar, with all its branches upright and close to the stem (fastigiate).

The young plants are somewhat sensitive to frost; but as they grow older they become quite hardy enough to stand our climate. In low-lying humid localities the shoots are sometimes not fully matured before early frost comes, but they are not usually damaged on dry airy situations. The largest specimen reported to the Conifer Conference in 1891 was 40 ft. in height, and had a girth of 1 ft. 9 in. at 5 ft. from the ground. It was growing on the estate of Keir (Perthshire).

The oldest and largest Cypress in Europe is probably that near Somma in Lombardy, which was noted for its size and beauty even as early as Cæsar's time. A still older tree of the same species was that at Sparta, which was in 400 B.C. mentioned by Pausanias, and which was destroyed with fire by Gipsies in 1881: it was 173 ft. in height, 33½ ft. in girth, 83 ft. in diameter of the crown of foliage, and was supposed to be about 3000 years old (Willkomm).

Economic Value.—Like the Yew, to which its resemblance is in many respects very close, its fragrant wood is of good quality and very durable. In some Italian buildings it is known to have stood from 600 to 1000 years, and is still sound; and in Candia and Malta it is considered the most durable of all timber. It is only of arboricultural interest in Britain.

Soil and Situation.—It thrives best on a deep, dry, sandy loam, in an open and airy but not exposed situation. It grows, however, on any moderately light and dry soil, even although somewhat exposed; but low damp spots are not suitable for it.

Cultivation.—The seed ripens in Britain, and the cones may be gathered early in spring. These generally open on being heated to about 100° Fahr. when the seeds fall out. The seed should be sown about the middle of April, in light well-prepared soil on warm-lying beds. The young seedlings come up about six weeks after sowing. They should be protected during the first winter, as they are liable to be injured by frost. They should be transplanted into nursery-rows when one year old, and re-transplanted two years later to stimulate the formation of fibrous roots.

There are also several other species and many varieties of this genus that are either raised from seed or else propagated by cuttings as ornamental trees. These other species include, among many others, *C. horizontalis* Miller, with pointed needles and marbled brown cones, and *C. glandulosa* Hooker, a small shrub-like tree with blunt oval needles, having an oil-gland pitted into the back of each needle. They all closely resemble the Common Cypress as regards treatment in the nursery.

(2) THE LARGE-CONED CYPRESS, *Cupressus macrocarpa* Hartweg.

SYNONYMS—*Cupressus Lambertiana ; C. Hartwegi* Carrière.

Specific Character.—*Leaves* ovate, imbricated, in four rows, bright grass-green, and closely set upon the old plants; they are expanded, awl-shaped, sharp-pointed, and thickly set upon the young plants. *Branches* irregularly spiral, but sometimes alternate or opposite; younger ones and laterals opposite, dense, and quite green; older branches dark-brown, and nearly horizontal from the main stem. *Cones* in clusters of three or four together, oblong, from 1 to 1½ in. long, and nearly 1 in. broad, with ten scales, the larger dark-brown, and more or less angular. *Seed-leaves* in fours, but sometimes only in threes. *Seeds* angular (Gordon).

Distribution.—This species is indigenous to the wooded heights near Monterey, in Upper California. Hartweg found it there with a height of 60 ft., a stem of 9 ft. in circumference, and a far-spreading, branching, flat top, like a full-grown Cedar of Lebanon, which he says it very much resembles when old. It was introduced into Britain in 1838.

Description.—This stately and graceful Cypress is sometimes found in nurseries and arboreta under the name of the Lambert Cypress (*C. Lambertiana*); and Gordon, in his *Pinetum*, p. 65, says that the two are identical:—

"That there is some difference in the shape of the plants may be, but then it arises from nearly all of those plants known under the name of *C. Lambertiana* being raised from cuttings, whereas those called *C. macrocarpa* are seedling, and have a more pyramidal-shaped head, while the cutting plants (*C. Lambertiana*) have a horizontal and rather flat-headed appearance."

But even in its wild state the tree may assume a flat top, though trees raised from cuttings have a much greater tendency to run into branches than those grown from seed.

It is a beautiful tree, with bright grass-green foliage. It is of rapid growth when young, but the rate diminishes as the tree gets old. It has rather a spreading horizontal habit of growth, but it does not assume this till of considerable age, and then it begins to exhibit a Stone Pine or Cedar-like characteristic. Though not so hardy as the Lawson Cypress, it thrives in Scotland when planted on dry and airy situations; but in low-lying and humid localities, where its young wood does not become properly matured early in autumn, it is liable to be injured by frost. Its best growth takes place near the coast of Southern and Western England, where it can sometimes attain a height of 80 ft. at fifty years of age. The two largest specimens reported to the Conifer Conference of 1891 were respectively 82 ft. high, with a girth of 10 ft. 7 in., and 64 ft. high, with a girth of 9¼ ft. at 5 ft. from the ground. The former was growing at Carclew (Cornwall), and the latter at Coollatin (Co. Wicklow). In 1903 the Coollatin tree (52 years old) girthed 10¼ ft., but the top was broken in the gale of February 1903; and the next largest reported was 68 ft. by 9½ ft. (Kent, 49 years; it was 61 ft. by 8 ft. in 1891).

Economic Value.—The timber belongs to much the same class as Spruce and Silver Fir, being soft, pale, and easy to work. The tree is, however, only of arboricultural interest.

Soil and Situation.—It thrives on soil and in situations suitable for the Common Cypress. It does best on dry ground, and on moderately airy situations, but should not be planted on low, moist, frosty localities. It thrives better in a mild part of the country bordering on the sea than on situations far inland, because the sea-breeze and a humid atmosphere seem more favourable to its growth than the drier climate of high-lying inland tracts.

Cultivation.—It produces seed freely, and may easily be grown from it in the same way as the Common Cypress. Its early rapidity in growth is such that seedlings are often 3 ft. high at three years of age. It may also be propagated by slips or cuttings, as is often done in the absence of seed, or in order to perpetuate varieties and sports; but plants grown from seed are always more vigorous than those reared from cuttings, are less branching in habit, and attain greater longevity. It easily bears transplanting either in autumn or in spring.

2. THE FALSE CYPRESS, *Chamæcyparis* (LINNÆAN SYSTEM, MONŒCIA MONADELPHIA).

Generic Character.—*Male flowers* terminal, forming cylindrical or ovoid catkins, and consisting of oval or shield-like anthers ranged crosswise oppositely, and each with 2 or 3 round anthers on the lower side. *Female flowers* terminal, round, consisting of scales, also ranged crosswise oppositely in groups of seldom more than 6 or 8, bearing 2 or 3 upright ovules. The *leaves* are like those of the true Cypress; but those on the upper and under sides of the twigs are flat, whilst the marginal leaves at the edges are folded together, so as to give the twigs a flattened appearance like those of the true Arborvitæ (*Thuja*). *Cones* small; round, angular scales, having a knob in the middle, which opens wide in order to scatter the seed when the cones ripen. *Seeds* compressed, and surrounded by a membranaceous wing. *Monœcious trees*, whose seed ripens in one year (Willkomm).

The plants belonging to the subgenus *Chamæcyparis* (=genus *Chamæcyparis* of Spach, Parlatore, and others), together with the genus *Retinospora* of Siebold and Zuccarini, differ from the true Cypresses in having generally two-ranked branchlets and flattened branch-systems; smaller cones ripening in the first year; the scales less woody, and usually with a smaller number of seeds. They are referred to *Thuya* by Bentham, but in their globular cones, peltate scales, and general habit seem more fitly to belong to the Cypresses (Masters).

This very handsome evergreen genus consists of many species and innumerable varieties, many of which are quite distinct from an arboricultural point of view, and all of which are worthy of cultivation, as they are free-growing, ornamental, and hardy, although thriving best in sheltered situations.

These different species and arboricultural varieties all more or less resemble in general habit and manner of treatment the *Ch. Lawsoniana*. They include, among many others, the following typical species: *Ch. nutkaensis* (see p. 280), *Ch. spheroidea* Sp. (*Cupressus thyoides* L., *Ch. glauca*, *Ch. thujoides*), one kind of "**White Cedar**" in America, and *Ch. ericoides* Carr. (*Retinospora ericoides* Zucc.) The two latter are handsome Juniper-like trees from North America (Virginia), which are hardy and form beautiful lawn plants. The *Ch. Fraserii* also belongs to this genus. It is a very distinct and beautiful species, with an erect compact habit of growth, and a strikingly rich glaucous hue.

(1) LAWSON'S CYPRESS, *Chamæcyparis Lawsoniana* Parlatore.

SYNONYMS—*Cupressus Lawsoniana* Murray; *Chamæcyparis Boursieri* Carrière.

Specific Character—*Leaves* on the adult plants ovate, in alternate opposite pairs, closely pressed, in four imbricated rows, and of a glaucous-green colour; while those on the young plants are lanceolate, sharp-pointed, spreading at the ends, whitish at the margins, and frequently furnished with a small gland on the back. *Branches* crowded, flexuose, and more or less ascending. *Branchlets* very slender, flattened on the upper and lower surfaces, much divided, bending alternately inwards and outwards, and thickly covered with decurrent leaves in alternate opposite pairs, closely pressed together on the adult plants, but spreading on the younger ones. *Cones* solitary, terminal, many-sided, of a light-brown colour, covered with a glaucous bloom when young, and about the size of a large pea, on rather a short footstalk. *Scales* mostly 6 in number, but sometimes more, flat, with a rough external surface, of a corky texture, light-brown, and irregularly 4- or 5-sided, with an elevated straight point in the centre. *Seeds* somewhat ear-shaped, rather large, and mostly 3 under each scale (Gordon).

Distribution.—This fine Cypress is found in the Shasta and Scots valleys, and along the banks of streams in the mountains of Northern California, in lat. 40° to 42°, where it forms the handsomest of the forest-trees. It was introduced into Britain in 1854.

Description.—In beauty of foliage, graceful habit, and hardiness, this is one of the most ornamental of Cypress-like trees. It grows to about 100 ft. in height, with a stem of 2 ft. in diameter. The branches first curve upwards like those of the Spruce, and then hang down at the ends like ostrich feathers. The two largest specimens reported to the Conifer Conference of 1891 had respectively a height of 55 ft., with a girth of $4\frac{1}{3}$ ft., and a height of 34 ft., with a girth of $8\frac{1}{2}$ ft. at 5 ft. above the ground. The former was growing at Dupplin (Perthshire), and the latter at Torloisk (Argyllshire). In 1903 the largest reported was 57 ft. by 5 ft. (Kent, 37 years).

Economic Value.—In California its timber is held in high estimation, and is much used for building. The wood produced in Britain is compact, close-grained, and somewhat resinous. It is not only suitable for ornamental plantations, but is also perhaps worthy of sylvicultural attention on account of the rapidity of its growth, its hardiness, and the good quality of the wood. It is not, however, likely to compete, as regards profitable cultivation, with the Douglas Fir. It is suitable for intermixing with *Thuja* and other Conifers, as it grows fairly fast and endures side-shade.

Soil and Situation.—The Lawson Cypress is quite hardy, and does fairly well on most kinds of soil and situation that are neither wet nor too much exposed. It can make leading-shoots of fully 12 in. a-year on soil varying from a light sand to a heavy clayey loam, and on situations up to 800 ft. above the sea-level. Its best growth is achieved on a good dry loam and in a sheltered situation.

Continental Notes.—The results of German sylvicultural experiments show that this tree thrives best on a dry or merely fresh, but not moist, sandy soil; and that during the youngest stages of growth it is only sensitive to winter frost when it is suddenly exposed to full sunshine after having had some shelter from standard trees. Young plants require shelter, however, as they are somewhat sensitive to late frosts. It is treated like the Spruce as regards planting and tending.

Cultivation.—The tree produces fertile seeds here, and plants can be raised from them in the same way as the Common Cypress. It can also be very readily propagated by cuttings.

(2) THE NOOTKA SOUND or ALASKA CYPRESS,
Chamæcyparis nutkaensis Spach.

SYNONYMS—*Cupressus nutkaensis* Lambert ; *Thujopsis borealis* Hortor.

Specific Character.—*Leaves* in four rows, in opposite pairs, broadly ovate at the base, sharp-pointed, and $\frac{1}{8}$ of an inch long, very thick, smooth, of a glossy green, when young sometimes a little glaucous on the upper side, and pale dull-green below, convex on the back, decurrent, and closely adhering at the base ; adult needles much shorter, awl-shaped at the points, keeled on the back, without any gland, but furrowed and closely imbricated ; those on the young plants glaucous, somewhat lanceolate, quite straight, extending at the points, loosely imbricated, and bristle-pointed. *Branches* round, spreading, or curved upwards towards the ends, but sometimes those near the bottom of the trees are more or less deflected, scaly from the withered leaves, and of a brownish colour ; lateral branches in two rows, regularly placed alternately on each side, flat and flexible ; *branchlets* in two rows, 4-sided, rather distant, extended, and thickly covered with short, straight, regularly imbricated leaves. *Cones* solitary, globular, almost sessile, or on the ends of very short scaly branchlets, about the size of a large pea, and covered with a glaucous bloom. *Scales* small, rough, and from six to eight in number, embossed, shield-shaped, with four or five angular or orbicular sides, elevated in the centre, in alternate opposite pairs, furnished in the middle with a straight, thick, conical, obtuse point, the lower pair much the thinnest, and very closely inserted at the base. *Seeds* mostly three under each scale, freely inserted on the interior of the upper surface of the scales, flat, and ear-shaped, with a bony shell along each side, and a membranaceous wing, frequently much broader than the seeds, and cut more or less sloping to the bottom (Gordon).

Distribution.—This species is found along the north-west coast of North America, and particularly at Nootka Sound, in Observatory Inlet, and on the island of Sitka. It was introduced into Britain in 1850.

Description.—This beautiful and hardy species of Cypress, of a graceful habit of growth, in many respects resembles the Lawson Cypress, and grows to a large size in California. But it is easily distinguishable from this by having the male catkins yellow instead of crimson, and by having a much more robust appearance, although not so graceful in habit of growth. Further, the scales of its cones number six to eight, while those of the cones of the latter are seldom more than six ; and its fruit, which takes two years to mature, has short blunt spines. The foliage of the Sitka Cypress is also harder, and of a paler green, than that of Lawson's Cypress, and the plants are, generally speaking, not quite so well foliaged. It is perhaps the hardiest species of Cypress that has been introduced into Britain. In 1903 the largest specimens reported were 45 ft. by 6⅔ ft. (Ross, 30 years) and 47 ft. by 3½ ft. (Lincoln, 48 years ; it was 40 ft. by 2½ ft. in 1891).

Economic Value.—The Sitka Cypress furnishes one of the best timbers of British Columbia, but very little is yet known about the quality of the timber produced in our climate. In any case, however, its interest is mainly arboricultural.

Soil and Situation.—This is a very accommodating kind of tree, which grows well on most soil which is not wet, and in most situations that are not too high and exposed. It does fairly well even on poor limestone, and will thrive wherever our common broad-leaved trees succeed.

Cultivation.—The Sitka Cypress may be grown from seed, though in our nurseries it seems to be more usually raised from cuttings. The method of treatment is similar to that for the other species. It seems to be hardy in every respect, and bears a fair amount of shade, so that it is suitable for fairly close planting.

(3) THE OBTUSE-LEAVED or JAPAN CYPRESS,
Chamæcyparis obtusa Endlicher.

SYNONYMS—*Cupressus obtusa* Koch ; *Retinospora obtusa.*

Specific Character.—*Leaves* mostly in whorls of four, ovate-rhomboid, blunt, seldom pointed, decussate, all scale-like, closely pressed along the branchlets, and adhering almost as far as the points, the lower part only being visible ; the leaves along the upper and under rows are ovate-rhomboid, obtuse, and seldom acute, while the side or lateral leaves are keeled, and lapping over at the edges, somewhat pointed, and almost sickle-shaped ; those on the younger plants are more open, longer, and remain persistent for several years. *Branches* spreading ; lateral branches in two rows, very dense, spreading out like a fan, and of a light shining green colour. *Cones* solitary, on the ends of the branchlets, globular, about the size of a small grape, with eight or ten scales in alternate opposite pairs (Gordon).

Distribution.—This tree forms large forests (in admixture with *Ch. pisifera*) in Central Japan at an elevation of 1000 to 6000 ft. It was introduced into Europe in 1862.

Description.—It is a tall evergreen tree, from 100 to 150 ft. high, and with a stem 4 to 7 ft. in diameter. It assumes very much the habit of an Arborvitæ (*Thuja*), but is easily distinguishable by the more spreading habit of the branches, and by these having a fan-like appearance. The largest specimen reported to the Conifer Conference of 1891 had a height of 23 ft., and a girth of 2 ft. 7 in. at 3 ft. above the ground. It was growing at Carclew (Cornwall).

Economic Value.—The wood is white, fine-grained, compact, and durable. But the tree is only of arboricultural interest here, although it is the most important coniferous tree in Japan.

Soil and Situation.—In Japan it is a tree of the mountains. It grows well on most kinds of soil, but requires a sheltered situation, though it is otherwise hardy. It has been strongly recommended for cultivation in the German woods, and is said to be suitable for growing wherever the Oak can thrive.

Cultivation.—The seed is best sown in a cold frame, and transplanted as yearling seedlings into the nursery lines, where they should stand for two or three years before being planted out.

There are several varieties of this species, whose names,—*alba*, *aurea*, *erecta*, *compacta*, *nana*, &c.,—as given in nursery lists, indicate their special peculiarities. They are perpetuated by cuttings, grafts, and layers.

3. THE TRUE ARBORVITÆ, *Thuja* (*Thuya*).

(LINNÆAN SYSTEM, MONŒCIA MONADELPHIA).

Generic Character. — Evergreen shrubs or trees with flattened branch-systems, minute adpressed *leaves*, globular or oblong *cones*, the *scales* of which are thickened upwards (not peltately expanded as in *Cupressus*). The two uppermost pairs of scales are fertile (not one only, as in *Libocedrus*). *Seeds* usually winged equally on both sides (whereas *Biota* has wingless seeds : Masters).

The Thuja or Arborvitæ sub-tribe consists altogether of large evergreen trees or shrubs, found in North-east America, California, and Japan. They are of a very slow rate of growth. Their scale-like leaves assume a dirty reddish-brown colour during severe winter cold, but they resume their natural dark-green colour with the return of active vegetation in the following spring.

(1) THE COMMON or AMERICAN ARBORVITÆ, *Thuja occidentalis* L.

Specific Character.—*Leaves* very small, in opposite pairs, ovate-rhomboid, blunt-pointed, closely imbricated and flattened, thickly pressed along the branchlets, in four rows, and with an elevated gland on the back of the upper and under leaves, which are the broadest, while those at the margin lap over on both sides; the leaves on the older branches are more distant, acute, extended at the points, decurrent, of a dull yellowish-green, and strongly scented when bruised. *Branches* distant, horizontal, and irregularly scattered along the stem; smaller branches drooping, and twisted in various directions. *Branchlets* spreading out laterally, numerous, two-edged, alternate, short, flattened, ramified, and covered with numerous small leaves of a bright shining green colour. *Cones* obovate, ½ of an inch long, solitary, on short footstalks, and covered with small scale-like leaves. *Scales*, each containing two seeds, and mostly six in number, oblong, spreading at the points, the centre scale truncate and divided to the base. *Seeds* very small, surmounted by a short wing (Gordon).

Distribution.—This species, one of the several kinds of trees that produce the so-called "White Cedar" of America, is found in most parts of North America, from Canada southwards to Virginia and Carolina, but mostly in Canada, where, forming pure woods or mixed with the American Larch, it occupies the wet and swampy tracts throughout the forest districts. It was introduced into Britain about 1566, or somewhat later.

Description.—In the American woods it grows from 70 to 90 ft. high, with a stem 2 to 4 ft. in diameter. It has there a conical crown of foliage, and its trunk is clothed with loose, open, spreading branches down to the ground. It is a very hardy tree, useful where shelter and ornament are required on exposed situations.

It is, however, less ornamental than the Giant Arborvitæ; for it is seldom so well clothed with branchlets and slender twigs, nor is it so graceful in its general habit of growth.

Economic Value.—The timber is very light in texture, but durable. In America it is much used for fencing, and palings made of it last a very long time. It is also much used for house-building, as it makes a light roofing timber, which under cover outlasts most kinds of Pine-wood.

Soil and Situation.—Although it grows well on most kinds of fairly good soil and situation, still it will only attain large size on deep, porous, fresh soil, and in a low sheltered situation. It is always in America found growing along the sides of streams, or on swamps where there is ample moisture for its roots; and the best trees are generally in sheltered situations near the sides of rivers, where there is plenty of moisture, but not stagnant water.

Cultivation.—It is easily propagated either by seed or by cuttings. The best plants are raised from American seed.

(2) THE GIANT ARBORVITÆ or RED CEDAR OF BRITISH COLUMBIA, *Thuja gigantea* Nuttall.

SYNONYMS—*Thuja Lobbii* Hortor; *T. Menziesii* Douglas; *T. Craigiana* of gardens.

Specific Character.—*Leaves* in alternate opposite pairs, closely imbricated, and without any gland on the back; those on the branches are more distant, enlarged at the base, decurrent, and tapering to an acute point, while the needles on the branchlets are very flat, closely placed, regularly imbricated, in four rows, much shorter, more rounded, and furnished with a short spiny point, the marginal leaves being more or less lanceolate, bristle-pointed, and lapping over on each side, but extended at the points. *Branches* spreading, flat, horizontal, irregularly scattered along the stem, slender, and of a deep-brown colour. *Branchlets* flattened, short, slender, flexible, and alternately two-rowed. *Cones* small, oval, tapering to both ends, nodding, and solitary at the extremities of the short branchlets (Gordon).

Distribution.—This species is indigenous to the north-west coast of America, and on the Californian mountains, where it is usually found at about 5000 ft. elevation. It was introduced into Britain in 1854.

Description.[1]—In the Californian mountains it attains a height of 50 to 100 ft., with a stem 2 to 5 ft. in diameter. It is well clothed with long flexible branches, thickly set with branchlets and inconspicuous foliage. It is a thoroughly hardy species, and thrives on most kinds of soil and situation where our common broad-leaved species of trees succeed. It is of rapid growth, and soon becomes a beautiful, well-clothed, and middle-sized tree. In Britain, under favourable circumstances, it attains a height of over 70 ft., and a girth of over 6 ft., at fifty years of age. Its hardiness is one of its great recommendations, as it can establish itself on rather exposed localities where many of the other ornamental Coniferæ succumb. The largest specimen reported to the Conifer Conference of 1891 had a height of

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[1] A monograph on *The Giant Arborvitæ* (Thuja gigantea) will be found in *Trans. Scot. Arbor. Socy.*, vol. xii., part ii., 1889, pp. 341-350.

The Giant Arborvitæ is next to the Douglas Fir in importance in British Columbia, where it attains its greatest size on Vancouver Island, along the coast and in the lower parts of the rivers of the Coast Range. It is rarely found in the dry interior of British Columbia, but is abundant in the river valleys on the slopes of the Selkirk and Coast Ranges. Though seldom found more than 150 ft. in height, in circumference it rivals the Douglas Fir, trees of from 8 to 10 ft. in diameter not being rare, and they are occasionally found much larger. It is chiefly used in the manufacture of shingles, for which purpose it is unequalled by any other wood (Macoun, *The Forest Wealth of Canada*, 1902, p. 31).

65 ft. and a girth of 6 ft. at 5 ft. from the ground. It was growing at Linton Park (Kent).

Economic Value.—The bright yellow or reddish wood of this tree is fine-grained and durable, and takes a good polish. In British Columbia the "Red Cedar" is largely used for interior work, but the wood produced in Great Britain is softer and less durable; and on the whole it is not a tree which has anything like the same value as Douglas Fir for planting with a view to profit. It is, however, about equal to Douglas Fir in shade-enduring capacity, and is suitable for planting, or underplanting, in patches at 4 by 4 ft., as its wood is better than Spruce or Silver Fir, and it endures more shade than these do in Britain. It is mainly of arboricultural interest here.

Soil and Situation.—It is hardy as to frost, and accommodating as to soil; and it suffers little from insect attacks or fungous diseases. It can thrive wherever our common broad-leaved trees succeed; but it attains its largest dimensions on a deep fresh soil and in a sheltered situation. It seems to do well on limy soil, and on land that is somewhat too moist for Larch.

Cultivation.—This species is easily raised from seed, which is freely produced in this climate, even at several hundred feet elevation. It may also be propagated from cuttings.

It is easy to cultivate, and can be planted out either in autumn or spring. It is of more rapid development than most trees of this class. At three years of age it not infrequently attains a height of 2 ft., and after that it soon shoots ahead if not disturbed in growth or by the side pressure of other trees. If planted along with Douglas Fir, it soon gets completely outgrown, and becomes suppressed by the latter, though capable of bearing a good deal of shade. Even when mixed along with Larch and Scots Pine, it has (at from twenty to forty years of age) to be protected against the encroachments of these, in order to be able to maintain itself (*e.g.*, as may be seen in the Ballyreagh plantation, Powerscourt, Co. Wicklow).

4. CHINESE ARBORVITÆ, *Biota*

(Linnæan System, Monœcia Monadelphia).

Generic Character.—The genus *Biota* differs from *Thuja* only (1) in its thickened *cone-bracts* being bent into a hook-like shape at the apex, (2) by their having two *unwinged seeds* at their base, and (3) by having a *longitudinal furrow* channeled along the back of the leaves in place of being provided with an oil-gland.

THE CHINESE ARBORVITÆ, *Biota orientalis* Don.

Synonym—*Thuja orientalis* L.

Specific Character.—*Leaves* on the adult plant very small, in four rows, ovate-rhomboid, acute-pointed, scale-like, imbricated, adpressed, decurrent, and furrowed along the base, the outer or marginal leaves lapping over on both sides, the upper and lower needles flat, with the points thickened, glaucous green and shining when young, but afterwards dull-green when old and glandless. *Branches* somewhat vertical and horizontal at first, but soon afterwards turning up at the ends, and finally becoming fastigiate with the stem. *Branchlets* disposed in two rows, densely crowded along the extremities of the branches, and placed sideways. *Cones* ovate-elliptic, 6-valved, solitary at the ends of the small branchlets, ½ an inch long, green when young, but light-brown when ripe, and composed of six scales, two being central, and four around the sides. *Scales* blunt, the central scales being truncate, with a short stout projecting point below the apex, and each scale covering two naked, egg-shaped, somewhat angular, wingless seeds (Gordon).

Distribution.—This tree grows indigenously in rocky situations throughout China and Japan.

Description.—The Biota is a beautiful evergreen tree. The densely-foliaged branchlets give a much more compact look than is shown by any other Conifer, and its rich deep-green colour contrasts well with other trees along the sides of roads in plantations. It seldom grows to over 25 ft. in height, and is merely of arboricultural interest.

Economic Value.—It has more the character of a large bush than a timber tree, and in any case is only ornamental.

Soil and Situation.—It grows well on almost any dry soil, and in any situation not too exposed.

Cultivation.—It is easily grown from seed sown in a cold frame. The seedlings should be transplanted into the nursery-rows when one year old, and should stand there two or three years, till they reach the required height.

5. THE INCENSE CEDAR, *Libocedrus* Endlicher (LINNÆAN SYSTEM, MONŒCIA MONADELPHIA).

Generic Character. — Trees with flattened branch-systems; *leaves* small, flattened, decussate; *male flowers* in spikes, anther-lobes 4; *cones* oblong, woody, with 2-6 valvate scales, of which the middle pair is alone fertile. *Seeds* with 2 unequal wings. *Cotyledons* 2 (Masters).

THE DECURRENT-LEAVED ARBORVITÆ, *Libocedrus decurrens* Torrey.

SYNONYMS—*Thuja Craigiana* Murray. It is often misnamed *Thuja gigantea* in gardens.

Specific Character.—*Leaves* on the young plants awl-shaped, somewhat lanceolate, decurrent at the base, extending at the apex, and sharp-pointed, loosely imbricated in four rows, thickly set on the branchlets in opposite pairs, the outer or marginal pair being longest, and folded partially over the inner pair on both sides, giving the young shoots a jointed trident-like appearance. Leaves on the adult plants very small, scale-like, $\frac{1}{12}$ of an inch long, and $\frac{1}{24}$ of an inch wide, ovate, blunt-pointed, thick in texture, in close opposite pairs, rather distant along the branchlets, pale-green, and shining, the marginal leaves overlapping the sides, and having the appearance of being in three rows on each side. *Branches* rather erect, long, slender, and spreading laterally, with numerous smaller branches. *Branchlets* short, flattened, channeled along the sides, distantly jointed, many, short, and alternate. *Cones* erect, solitary on the ends of the upper branchlets, oblong, tapering to the points, 1 in. or more in length, and $\frac{1}{2}$ an inch wide near the base, and composed of two opposite pairs of scales, with a flat scale down the middle, and of a pale olive-brown colour (Gordon).

Distribution—This tree is plentiful along the north-west coast of America, near the banks of the Columbia River, on the mountains of Northern California, on the Sierra Nevada, and along the Sacramento River.

Description.—It is an evergreen tree, ranging up to 140 ft. in height, and with a stem 3 to 5 ft. in diameter. It is a free grower and quite hardy. The tallest specimen reported to the Conifer Conference in 1891 had a height of 50 ft.; while another stem having a height of 37 ft. had a girth of $6\frac{1}{4}$ ft. at 5 ft. above the ground. The former was growing at Orton (Huntingdonshire), and the latter at Torloisk (Argyllshire). In 1903 the two largest reported were 63 ft. by 6 ft. (Huntingdon, 45 years) and 70 ft. by 5 ft. 2 in. (Bucks, age uncertain).

Economic Value.—This wood is also called "White Cedar" in America, and is much used throughout California, where it is durable.

Soil and Situation.—As detailed for the Giant Arborvitæ.

Cultivation.—This Arborvitæ is grown chiefly from seed, and in the same way as the Giant Arborvitæ.

6. THE JUNIPER, *Juniperus* L.
(LINNÆAN SYSTEM, DIŒCIA MONADELPHIA).

Generic Character.—*Male flowers* axillary or terminal catkins; female flowers, small axillary bud-like bodies, bracteated at the base. *Fruit*, a globular kind of berry, composed of a fleshy or fibrous juicy substance, covered with a glossy skin, more or less furnished externally with minute scales, and somewhat angular and naked at the apex. *Seeds* from one to five, but mostly three, in each fruit, obscurely three-cornered, and covered with a hard bony covering, having gland-bearing pits towards the base. *Leaves* simple, opposite or ternate, lanceolate or scale-formed, and either in extended whorls or closely imbricated in four rows. *Seed-leaves* in twos (Gordon). This genus is easily recognised by its peculiar odour and by the globular cones of 3-6 fleshy valvate scales in which the erect seeds are imbedded. Male flowers in spikes, anthers crested, 3-4 lobed, pollen globose. Embryo with 2 blunt leafy cotyledons. Primary leaves pointed (Masters).

The genus **Juniper** consists altogether of 34 species of small evergreen trees or shrubs, indigenous to the temperate and frigid regions of Europe, Asia, Africa, or America.

As the Common Juniper is only a shrub, and very often a weed in place of being a useful plant, only one species of this genus need here be referred to in detail, the Red Cedar. It is a hardy and ornamental tree, and one of the tallest and hardiest of the genus.

A large number of other introduced species are much admired as beautiful shrubs and small trees. These include *J. canadensis*, *J. chinensis*, *J. hibernica*, *J. japonica*, *J. macrocarpa*, and *J. oxycedrus* among the shrubs; and *J. phœnicea* and *J. Sabina* among the smaller trees. They all have very much in common with the Red Cedar, so far as arboricultural treatment is concerned.

For the formation of quaint live-hedges in old-fashioned gardens our Common Juniper, *J. communis*, is worthy of the attention of horticulturists.

THE VIRGINIAN JUNIPER or RED CEDAR,
Juniperus virginiana L.

SYNONYMS—*Juniperus arborescens* Monch.; *J. Caroliniana* Du Roi.

Specific Character.—*Leaves* in twos, opposite, and 4-rowed, but frequently in whorls of three on the young shoots; those on the adult plants closely imbricated, very small, and sharp-pointed, but afterwards as they get older become spread out at the points, glossy and light-green in the common form of the tree, but frequently becoming of a tawny-brown colour in winter. *Branches* horizontal, numerous, close together, and feathered to the ground. *Branchlets* 4-sided, slender, straight, spreading, and very numerous on the outer parts of the branches. *Berries* dark-purple, small, ovate, smooth, or slightly warted on the surface, and covered with a white glaucous powder when ripe. *Male and female flowers* sometimes on the same plant, and sometimes on separate ones (Gordon). .

Distribution.—This species is found throughout the eastern States of America, from Cape Florida and the northern shores of the Gulf of Mexico up to the State of Maine and the Cedar Isles in Lake Champlain, extending through about 48° of latitude, from 20° to 68°, but is not now plentiful in any particular district. On the sides of low hills in the valley of the Gateneau River it grows along with the Red Pine (*P. resinosa*) on ridges and knolls having a poor soil, but not on low-lying parts of the country or on rich soil. It was introduced into Britain in 1664.

Description.—The Red Cedar is a handsome tree, well clothed with branches and foliage when standing free. Even in America it seldom is over 50 ft. high or more than 18 in. diameter, and it is generally smaller. In Britain it grows as well as it does in its native woods. The leaves are variable in form—needle-shaped, lanceolate, oval or ovoid, and round; while at the same time both blunt and sharp-pointed leaves are common on the same branch. Sometimes the leaves are in pairs, sometimes in whorls; sometimes short, and sometimes long; and they often vary in colour from green to silvery glaucous and purple. It is of upright habit and rather conical in shape, and its thick foliage screens plants near it.

Like the Common Juniper, this American species is well suited for ornamental hedges. The largest specimen reported to the Conifer Conference of 1891 had a height of 70 ft. and a girth of 6 ft. at 5 ft. above the ground. It was growing at Studley Royal (Yorkshire).

Economic Value.—Its timber is much used in America for cabinet-making, turnery, &c. It is chiefly with the "Red Cedar" wood of this tree that black-lead pencils are covered. The smallness of the stem and the slow rate of growth, however, render it quite unsuitable for planting with a view to profit, and it is only an ornamental tree in Britain.

Soil and Situation.—Red Cedar grows best on a good, deep, porous, light loam, resting on a dry subsoil, and in an airy but sheltered situation. It is in all respects hardy.

Continental Notes.—It has received some attention in the German forests, where it attains a height of from 40 to 60 ft., and has proved itself thoroughly hardy and accommodating as to soil. There it thrives best on fresh humose sand, and exhibits a preference for limy soil, though it can do fairly well on dry land, either of a light or a slightly binding character. In the colder northern parts of the country new strains of seed have to be obtained from time to time, as, owing to imperfect pollination, much of the seed produced fails to germinate when trees bearing only female flowers stand together.

Cultivation.—It produces seed from about the twelfth to twentieth year onwards. The seed often lies dormant for a year before germinating; but the young plants then coming up grow rapidly. They should be transplanted into nursery-rows when one year old, and should, until they reach the size wanted, be transplanted at least once every two years to check the growth of long root-strands and stimulate formation of fibrous roots.

The seedlings of this tree *sport* a good deal—*i.e.*, are apt to deviate individually more or less from the common specific type. From any one seed-bed several varieties are usually obtained, differing in leaves or in the habit and arrangement of the branches. Many of the varieties have special arboricultural names indicating their peculiarities. Thus there are *J. virg. var. alba, argentea, aurea, pendula, plumosa, cinereascens*, &c., which can all be grown from cuttings.

IV. TAXODINEÆ.

None of the genera forming this group of the *Coniferæ* is indigenous to Europe. They are chiefly found in tropical and subtropical Asia and the southern portion of North America (California and Mexico). They include important timber-trees in the countries where they are indigenous; but this climate is, even in its mildest parts, unsuitable for their cultivation in woodlands.

The Taxodium tribe (*Taxodieæ*).—Trees with narrow linear leaves, spirally arranged, sometimes apparently two-ranked, not whorled. Buds not scaly. Flowers monœcious. Cones globular or oblong; scales spirally arranged, more or less woody. Bracts partially consolidated with the scales. Seeds, 2-6 to each scale, erect or inverted, winged (Masters).

1. JAPAN CEDARS, *Cryptomeria*
(LINNÆAN SYSTEM, MONŒCIA MONADELPHIA).

Generic Character.—Evergreen trees with linear leaves, often heteromorphic. *Flowers* monœcious, males in axillary spikes; *anthers* crested, 4 or more lobed, *pollen-cells* globose. *Cones* globular; cone-scales palmately divided at the edge, so that the ripe cone is somewhat prickly. *Seeds* erect, 4-5 to each scale, slightly winged. *Cotyledons* 2-4, flat, leafy. *Primary leaves* in whorls of 3 (Masters).

There are two species in this genus both of which are large evergreen trees indigenous to Japan.

A Chinese genus (*Cunninghamia Sinensis* R. Brown; syn., *Belis jaculifolia* Salisb.), a tender small tree indigenous to Northern China, is cultivated in arboreta throughout many parts of the continent of Europe, but does not appear to have found much favour in Britain.

Both of the Cryptomeriæ or Japan Cedars are elegant in their habit of growth, have a very marked and distinctive appearance on lawns with other kinds of trees, and may be grown in almost any fairly sheltered situation. They are sometimes confused with the *Araucarieæ*.

(1) THE JAPAN CEDAR or COMMON CRYPTOMERIA,
Cryptomeria Japonica Don.

SYNONYMS—*Cupressus japonica* L.; *Taxodium japonicum* Brongn.; *Cryptomeria Fortunei* Koch.

Specific Character.—*Leaves* 5-rowed, without any footstalks, short-pointed, very close together, incurved or sickle-shaped, compressed on the sides, of a 4-sided, rhomboidal shape, running downwards on the under side, and with a sharp projecting midrib, from $\frac{1}{4}$ to $\frac{3}{4}$ of an in. in length, bright-green and quite smooth. *Branches* erect or horizontal, and spreading; lateral branches dividing alternately into numerous branchlets, thickly clothed with leaves. *Cones* about the size of a large cherry, mostly standing singly, but sometimes in clusters on the extremities of the branchlets, and without any footstalks, mostly erect, of a globular shape, and a dirty brownish-red colour, but not very compact or solid. *Scales* numerous, rather loose, of a dull brownish-red colour, and with rough fringed edges. *Male flowers* on the same tree, intermixed with the young cones, at the extremities of the branchlets, and of a small oval or oblong shape, in large loose clusters. *Seeds* ripen in September and October during the year of flowering (Gordon).

Distribution.—The Japan Cedar is plentiful about Shanghai and other parts of Northern China in the form of groves and avenues, but was introduced there from Japan. Thunberg found it both spontaneous and cultivated on the Nagasaki hills and in other mountainous districts of Southern Japan, at 500 to 1200 ft. elevation, where it is generally met with on damp soil. It was introduced into Britain in 1844.

Description.—It is a graceful handsome tree, which grows in Japan to a height of 100 ft., with a stem 3 to 5 ft. in diameter. It is hardy enough for the climate of Southern England and Ireland; but in Scotland, except in the milder parts near Nairn and Inverness, it only stands the harder winter on good soil and in warm situations where its wood can be thoroughly ripened. It has a natural tendency to ramify and spread laterally, and its ornamental effect is lessened if this be checked by close planting. The two largest specimens reported to the Conifer Conference of 1891 were respectively 67 ft. in height, with a girth of 5 ft., and $42\frac{1}{2}$ ft. in height, with a girth of $9\frac{3}{4}$ ft. at 5 ft. from the ground. The former was growing at Coollatin (Co. Wicklow), and the latter at Keir (Perthshire). In 1903 the Coollatin tree girthed 5 ft. 11 in. (50 years old), but had lost its top in the gale of February 1903.

There are several purely arboricultural varieties of this species—e.g., *Crypt. japon. var. elegans*, *gracilis*, *viridis*, *nana*, *Lobbii*, and *araucarioides*. The foliage of *C. j. elegans* changes in winter to a dull-red colour, which is very effective when contrasting with dark-green foliage.

Economic Value.—The wood is soft, white, and brittle; it is only of arboricultural interest in Britain.

Soil and Situation.—It is an accommodating tree, but grows best on deep, light, permeable soil, and in an elevated but sheltered situation. It thrives on sandy loams with moist subsoil, such as are often found near the edge of a stream. It does not stand exposure to cutting spring winds, which make its foliage brown and discoloured.

Cultivation.—The Japan Cedar is grown from seed, which should be collected in early autumn. It is also easily raised from cuttings.

(2) THE ELEGANT CRYPTOMERIA, *Cryptomeria elegans.*

Specific Character.—*Leaves* linear, narrow, sickle-shaped, rigid, acute-pointed, decurrent at the base, somewhat distinctly placed spirally all round the branchlet, and when fully grown bent backwards; they are slightly channeled on both sides, quite smooth, and of a cinereous or ash-greyish green colour in summer, but change to a rich bronze hue in the autumn and winter; they are from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch long, and only of about $\frac{1}{24}$ of an inch wide near the base. *Branches* numerous, horizontal, spreading, somewhat flat, and irregularly placed along the stem; lateral branches and *branchlets* alternate, curved downwards at the points, and in winter of a reddish-brown colour. *Cones* very similar to those of the Common Cryptomeria.

Distribution.—This species is found on the island of Nippon, in Japan, where it forms groves around sacred edifices, and is probably merely a perpetuated variety of *C. japonica.*

Description.—It is a tree of robust and branching habit of growth, whose foliage changes to a rich bronze, contrasting well with the autumn tints of other trees. In Japan it grows to 100 ft. high. The largest specimen reported to the Conifer Conference of 1891 had a height of 24 ft., and a girth of 1 ft. at 5 ft. above the ground. It was growing on the estate of Poltalloch (Argyllshire).

Economic Value.—It is merely of arboricultural interest.

Soil and Situation.—It is a fairly hardy species, which is accommodative as to soil, but grows best on moist, though not wet, soil and in a sheltered situation.

Cultivation.—Like the Japan Cedar, this species may also be grown from slips. But it is best to grow it from seed, as the trees have greater vitality.

2. THE MAMMOTH TREES AND REDWOODS OF CALIFORNIA, *Sequoia* (LINNÆAN SYSTEM, MONŒCIA MONADELPHIA).

(1) THE GIANT SEQUOIA or MAMMOTH TREE, *Sequoia gigantea* Torrey.

SYNONYMS—*Wellingtonia gigantea* Lindl.; *Washingtonia gigantea* Hort. Amer.; *Sequoia Wellingtonia* Seemann.

Generic Character.—Evergreen trees with small leaves, scattered, or apparently in two ranks. *Flowers* monœcious; male flowers in terminal stalked oblong or globose heads; *anther-lobes* 2-5; pollen globose. *Cone-scales* and bracts united into a woody, wedge-shaped, or peltate mass. *Seeds* 4-9, winged, without resin-canals (Masters).

Specific Character.—The *leaves* are all somewhat needle-shaped, spirally alternate, spreading, persistent, and of a light-green colour on the young plants; those on the adult trees scale-like, closely inlaid, rounded on the back, and concave on the inner face; those on the branchlets much shorter, very close, and regularly imbricated; those on the larger branches longer, looser, decurrent at the base, and tapering to an acute point, but sometimes rather acute. *Branches* spread out horizontally, much divided, and furnished with numerous laterals. *Branchlets* cylindrical, frequently pendulous, and thickly covered with light-green glaucous foliage; cone-bearing branchlets slightly thickened, and entirely covered with scale-like leaves, closely imbricated, the upper leaves oval, and broadest at the base. *Cones* solitary on the ends of the branchlets, about 2 in. long, and fully 1 in. in diameter, ovate, blunt-ended, and slightly tapering towards both extremities. *Scales* in series, placed nearly at right angles upon the axis of the cone, stipitate, or supported by a stalk, thickened, and enlarged from the point of insertion as far as the summit, which is depressed and wrinkled on the external face, and furnished with a small prickle in the centre of the little hollow. *Seeds* from five to six under each scale, but mostly in fives. *Seed-leaves* from three to six in number, but mostly in fours (Gordon).

Distribution.—The Mammoth Trees of California are confined merely to isolated groups here and there. They were in 1852 found near the head-waters of the Stanislaus and San Antonio rivers, in lat. 38° N., long. 120° 10″ W., at about 4590 ft. elevation, at the place called Calaveras Grove, where there are still nearly 200 trees standing, of which 92 are of large size. The next group, the Mariposa Grove, was discovered fifty miles south-east of that, at about 5000 ft. elevation on the western slope of a high ridge of the Sierra Nevada. The trees here are spread along a lateral valley, on the flank of a main ridge, in two groves (upper and lower), about half a mile apart, and containing nearly 600 trees of considerable size. A third grove, containing about 500 trees, was found in Fresno County, eight miles south-east of the Mariposa Grove, and a fourth grove farther to the south and east, upon the Kaweeab, some fifty miles from Visalia. These groves are protected within the Yellowstone, Yosemité, and Sequoia Reservations, the great National Parks containing the most charming scenery of the Californian forest districts, and including the celebrated "Big Trees," the "Bridal Veil" waterfall, &c. The Mammoth Tree was introduced into Britain by William Lobb in 1853.

Description.—This is the largest species of tree yet discovered. It attains 300 ft. in height, and 30 ft. in diameter near the ground; but it has been found about 400 ft. high, and nearly 40 ft. in diameter. Like Yew and Cypress, it attains enormous longevity. It is quite hardy even in the north of Scotland, though the foliage sometimes turns brown in a severe winter. The two largest specimens reported to the Conifer Conference of 1891 had respectively a height of 80 ft., with a girth of 8½ ft., and a height of 52 ft., with a girth of 13¾ ft. at 4 ft. above the ground. The former was growing on the Shanballey estate (Tipperary), and the latter at Castle Menzies (Perthshire).

Economic Value.—The wood is light, soft, and brittle. It is one of the very lightest of woods, for when seasoned it has a mean sp. gr. of 0·38, which is even lower than that of the Weymouth Pine, and considerably less than that of most other conifers. Even if the climate were mild enough for the tree to be grown as a timber-crop, it would have less claim to attention than the Douglas Fir, the Menzies Spruce, &c. It is merely an interesting tree of rapid growth and large dimensions.

Soil and Situation.—This is a tree that prefers rather a moist climate, and in so far Britain is naturally suited to it. It thrives best, however, on a deep dry soil, and in an open, but not exposed, situation. Its growth is less satisfactory on cold retentive land, or where the subsoil is wet; nor does it thrive if its crown is confined, or if exposed to high winds.

Cultivation.—The seed should be sown on a warm protected bed, and the seedlings transplanted into the nursery-lines when one year old, plenty of growing-space being allowed, as they grow quickly, and are light-demanding plants. They should be transplanted at least once every two years to make the roots more fibrous. Cuttings root freely and make good plants, though seedlings probably attain greater longevity.

It is found to do well as a forest-tree in the southern regions of Austria, where it has been largely planted by the State Railway Company throughout the Banat.

(2) THE CALIFORNIAN REDWOOD, *Sequoia sempervirens* Endlicher.

SYNONYMS—*Sequoia taxifolia* Koch ; *Taxodium sempervirens* Lambert.

Generic and Specific Character.—*Leaves* on the lateral branches and branchlets linear, blunt-pointed, 2-rowed, spread out, flat, alternate, straight, rarely falcate or bent like a sickle, leathery, persistent, shining, dark-green, and smooth above, more or less glaucous, and channeled below ; from ½ to 1 in. long, but much shorter and smaller near the extremities of the shoot ; those on the principal branches and terminal points of the flower-bearing branchlets are very short, narrow, sharp-pointed, or scale-like, somewhat imbricated or closely spiral, decurrent at the base, ribbed, and glaucous below, whilst those on the leading-shoots are distant and very acute. *Branches* spreading, horizontal, rather distant, irregularly scattered alternately along the stem, and furnished with numerous lateral branches in two rows, those nearest the base being frequently bent downwards, while those towards the extremity are more elevated ; *branchlets* very numerous, in two rows, and frequently drooping. *Male flowers* globular, solitary at the extremities of the branchlets, on slender footstalks, thickly covered with very small scale-like leaves. *Cones* solitary, terminal, somewhat globular or egg-shaped, rather blunt at the ends, and about 1 in. long. *Scales* numerous, wedge-shaped, from 16 to 20 in number, smallest near the base, transversely keeled, very much sunken in the middle, irregularly shaped, wrinkled on the summit, and furnished in the middle of the hollow centre with a stout, horn-shaped, blunt point, directed outwards. *Seeds* from 3 to 5 under each scale, variously shaped, and winged. *Seed-leaves* mostly in twos, but sometimes in threes, ovate-lanceolate, obtuse at the ends, slightly convex, and pale-green on the under side, but of a much darker colour and somewhat glossy above (Gordon).

Distribution.—The Californian Redwood was first discovered by Menzies in 1796, and afterwards by Douglas in 1836 ; later on it was again found by the Russians, who first introduced live plants of it into Europe in 1843. Since then it has been found growing abundantly on the mountains of Santa Cruz, about sixty miles from Monterey, in California, where Hartweg saw trees over 200 ft. high and 6 to 8 ft. in diameter. One tree, called "the Giant of the Forest," was 270 ft. high, and had a trunk 55 ft. in girth at 6 ft. from the ground.

Description.—It is quite a hardy tree in Central and Southern England, and also in favourable situations in the northern counties ; but it is unable to stand the long severe winter in Scotland. It is rapid-growing, and soon attains large dimensions on favourable situations, where it develops into an upright tree of noble proportions with Yew- or Spruce-like foliage. It is more graceful in general habit than the Mammoth Tree. The largest specimen reported to the Conifer Conference of 1891 had a height of 75 ft., and a girth of 13 ft. at 5 ft. above the ground. It was growing on the estate of Boconnoc (Cornwall).

Economic Value.—In California many lumber firms do a gigantic business in extracting and converting "Redwood," which is one of the staples of San Francisco trade. But its timber, although close-grained, is short-fibred and brittle, and is not of a very durable description. It has a beautiful grain, and is imported in small quantities for furniture and interior decoration. The wood produced in Britain is soft and light ; it is not at all durable, though it may be of use for such purposes as making packing-cases.

Soil and Situation.—In order to thrive well in even the milder parts of England, it requires a deep, light, permeable soil, and a sheltered situation. It starts growth very irregularly in spring, often shooting late in the season, and continuing growing late into autumn; and then it is only on favourable soil and in mild situations that it can mature its young wood against injury from frost. Too rich a soil is apt to make it grow late into autumn, only to be nipped by early frost.

Cultivation.—The seed is generally sown in frames, and the young plants gradually accustomed to exposure. They require protection for the first winter, and should have it for the seeond winter also in the colder parts of Scotland.

3. THE DECIDUOUS CYPRESS, *Taxodium* (LINNÆAN SYSTEM, MONŒCIA MONADELPHIA).

Generic Character.—Trees with deciduous foliage. *Male flowers* in branched catkins. *Anther-lobes* 5-8. *Cone-scales* thick, peltate; seeds erect, angular, with projecting points, but without wings. *Cotyledons* 6-9, 3-angular (Masters).

THE SWAMP CYPRESS or DECIDUOUS CYPRESS, *Taxodium distichum* Richard.

SYNONYMS—*Cupressus disticha* L.; *C. virginiana* Plukenett; *Schubertia disticha* Mirbel.

Specific Character.—*Leaves* small, $\frac{1}{4}$ to $\frac{5}{8}$ of an inch long, linear, tender, and ranged pectinately in two rows. *Branches* in whorls. *Cones* situated at the base of the shoots, either singly or in clusters of two or three, upright, of a spherico-ovoid shape, a spongy wooden consistency, and a dark-brown colour; they are from $1\frac{1}{8}$ to $1\frac{5}{8}$ in. in diameter, and take two years to ripen. *Seeds* in twos under each scale, upright, and unwinged.

Distribution.—This tree is indigenous to the subtropical swamps of Virginia, Louisiana, and Florida.

Description.—In America it grows to upwards of 120 ft. in height, with a girth of over 40 ft. In Britain it is also a singularly graceful deciduous tree of rapid growth. The two largest specimens reported to the Conifer Conference of 1891 had respectively a height of 30 ft., with a girth of 3 ft. 5 in., and a height of 27 ft., with a girth of $3\frac{3}{8}$ ft. at 5 ft. from the ground. The former was growing at Rossdhu (Dumbartonshire) and the latter at Revesby (Lincolnshire).

Economic Value.—The wood is resinous, and when freshly cut of a pale whitish colour, afterwards deepening into reddish with long exposure to the air. It is hard and durable, and is in America extensively used for furniture. It might possibly be grown profitably in Southern England for furniture-wood, but in the colder climate of Scotland it can have merely an arboricultural interest.

Soil and Situation.—It grows best near the margin of lakes or ponds, the edges of streams, and similar moist localities, as a considerable degree of soil-moisture is necessary for its requirements.

Cultivation.—It is a fairly hardy tree, which can easily be raised from seed in the open. Of rapid development, it can be planted out permanently at an early age.

B—PSEUDODRUPACEÆ WILLKOMM.

TAXACEÆ LINDLEY.

The *Taxaceæ*, the chief family of the natural order of the *Pseudodrupaceæ*, differ from the *Coniferæ* or true cone-bearers (1) by having only *one-seeded fruits* in the form of a fleshy pseudodrupe or false berry; (2) by the *seed*, which ripens in the autumn of the year of flowering, being surrounded and encrusted by a bony scale; and (3) by the *bark*, *wood*, *and leaves* containing no resin-ducts. The natural order is represented by five families; but only one of these is indigenous to Europe, and the other four are regarded by most botanists as mere tribal or generic forms of the *Taxaceæ*.

1. THE YEW, *Taxus* L. (Linnæan System, Diœcia Monadelphia).

Generic Character.—Evergreen trees, with 2-ranked *leaves*, *flowers* diœcious; *stamens* in stalked heads; *anther-scales* peltate; *pollen* globose; *seed* solitary, erect, and borne in a scarlet, fleshy cup or aril. *Cotyledons* 2, leafy, flat, green on both sides, without resin-canals. *Primary leaves* similar in form, but smaller (Masters).

The Yews are low evergreen trees or bushes, whose branches are irregular and not arranged in whorls. They are indigenous to the temperate parts of Europe, Asia, and America. The only species which need here be referred to is the Common Yew.

THE COMMON YEW, *Taxus baccata* L.

Specific Character.—*Leaves* in 2 rows, crowded, linear, slightly curved or falcate, pointed, flat, entire, and slightly revolute on the margins; from $\frac{3}{4}$ to $1\frac{1}{4}$ in. long, and $\frac{1}{8}$ of an inch broad, of a dark shining green above, much paler below, with a prominent midrib, terminating in a small point at the apex. *Branches* spreading, much divided, and dense. *Branchlets* long, slender, and drooping. *Male flowers* axillary. *Fruit* a false berry, rounded, glutinous, drooping, open at the top, and enclosing a brown, oval, partially naked nut, unconnected with the fleshy disc, which is of a scarlet colour, and sweet. *Seed-leaves* in twos (Gordon).

The development of the male flowers begins in the autumn, while the female flowers do not appear till spring. The leaf-buds do not open till about a week later than the flowering buds.

Distribution.—The Yew is found in most parts of Europe, throughout the southern portion of which it is a characteristic plant of the mountains, whereas in Northern Europe it is to be found at the sea-level. Its northern limit of spontaneous growth reaches to about 58° in Scotland and 61° in Norway; whilst its southern limit trends along the northern lands bordering the Mediterranean Sea from about 36° in Southern Spain to 37° in Greece, whence it stretches farther eastwards into the Caucasian Mountains at upwards of 2000 ft. elevation.

Description.—The Common Yew has a short, straight stem, which at 3 or 4 ft. sends out numerous spreading branches forming a dense head. When full grown it is usually from 30 to 40 ft. high, and is always characterised, except in very old trees, by the top-contour being pointed or peaked. After the tree has reached the stage of incipient decay, these angular points gradually become rounded off or the tree gets stag-headed. The stem and branches are channeled longitudinally, and are generally rough from the protruding remains of shoots which have decayed and fallen off. It is a tree of very slow growth; but in favourable situations reaches a height of 6 to 10 ft. in twelve years, when grown from the seed. The Yew attains a great age. Some of those in this country, as well as in other parts of Europe, are considerably over 1000 years in age; and many of them are supposed to be from 2000 to 3000 years old.

It is not uncommon to find the branches of trees growing into each other, though whether this has been due to natural causes or to artificial means, it is often hard to say. A fine specimen of this sort of arboricultural curiosity is to be seen at Rossanagh Park (Co. Wicklow).[1] Not infrequently some of the lower branches

[1] There are many fine Yews in Ireland of the spontaneous variety, the Irish Yew (*T. baccata hibernica* Hort., *T. hibernica* Hook).

assume a strong upward tendency, and develop like secondary stems. Examples of this are to be found in the 5-stemmed Yew at Withycombe (Devonshire), and the 12-stemmed Yew celebrated throughout Cardiganshire. In the Forest of Dean and the New Forest there are many remarkable Yews, which are traceable back to the days of William the Conqueror. At Temple Farm, Corsley (Wilts), there is a fine old tree upwards of 1000 years old; it is 50 ft. high, with a stem about 10 ft. in diameter, and has a spreading crown of foliage upwards of 50 ft. across.

The largest specimen of the Common Yew reported to the Conifer Conference of 1891 had a height of 40 ft., and a girth of 13 ft. at 5 ft. above the ground. It was growing on the estate of Rossdhu (Dumbartonshire). But in the old deer-park near Kentchurch (Hereford) there is a Yew which measures 30 ft. in circumference at 4½ ft. from the ground. In that same park there is also an Oak which girths 32 ft. 5 in. at 5 ft. from the ground, and a Scots Pine that girths 11 ft. 7 in. at the same height. In the old woods on the Sudbury Park estate (near Chepstow) there is an ancient Yew-tree having a girth of 21 ft. 4 in. at 5 ft. above the ground; its bole is 8 ft. long, and its total height 40 ft.

Economic Value.—The wood is very hard, close, fine-grained, flexible, and elastic; it splits readily, takes a high polish, is very durable, and is one of the best for cabinetmaking. In some parts of England where it is plentiful, it is proverbial that a paling-post of Yew will outlast a post of iron.

In ancient days, when it provided the tough bows for the English archers, it was a tree of national importance; and Yews planted in churchyards received legal protection early in the fourteenth century (see Part I., p. 19).

Soil and Situation.—The Yew will grow on most kinds of soil that are not too sandy and dry, but it thrives best on a fresh limy soil and in a damp climate. It has great power of enduring shade, and for the first few years it is less liable to damage from overshadowing than from drought and excess of direct sunlight.

Cultivation.—The Yew can be grown from cuttings, but it is best to grow it from seed, and only to propagate varieties from slips. The seeds ripen in October, and should then be gathered and washed free of pulp. As they lie dormant for one year, the pulped seeds should be mixed with about twice their bulk of sand, and pitted for fourteen or fifteen months. Then they should be sown on good loamy or limy soil, and covered with about ⅝ of an inch of earth. The seedlings should be transplanted into nursery-rows when two years old, and are fit for putting out whenever they reach the size wanted.

2. THE GINGKO, *Gingko* L. (Linnæan System, Diœcia Monadelphia).

There is only one species in this genus of the *Salisburineæ* tribe of the *Taxaceæ*.

THE GINGKO or JAPANESE MAIDENHAIR TREE, *Gingko biloba* L.

Synonym—*Salisburia biloba* Smith.

Generic and Specific Character.—*Leaves* deciduous, in fascicles of 3 to 5 or more on short alternate spurs of variable size; the footstalks 1 to 3 in. long, smooth on the outer and furrowed on the inner side; leaf surface fan-shaped, 2 to 3 in. broad, leathery, dull-green, with numerous veins of nearly equal size diverging from the top of the petiole and not connected by lateral reticulations; blade 2-lobed, with a cleft in the top margin varying much in depth according as the leaves are on sterile or fertile branches, and very shallow or almost obliterated on the latter. *Male flowers* sub-pendulous in umbels of 3 to

6 on the ends of short arrested branchlets or spurs, and intermixed with leaves; anther-lobes 2, pendulous and divergent. *Female flowers* in pairs on the apex of slender foot-stalks, each flower consisting of a single erect ovule arising from a cup-shaped dilatation of the axis. *Fruit* drupe-like, the fleshy outer covering of a greenish-orange colour enclosing a hard woody mesocarp or shell that contains the seed (Veitch's *Manual*, 1900, p. 109).

Distribution.—This is the sole survivor among many fern-leaved kinds of trees common all over the globe in previous geological periods. It is supposed to be still found growing wild in Corea, but for centuries it has been cultivated in China and Japan as a sacred tree near temples and shrines. It has been introduced into Europe and North America, and grows well on both of these continents. It was introduced into Britain about 1754.

Description.—The Gingko grows in China and Japan up to nearly 100 ft. high, and forms a good trunk up to between 6 and 7 ft. in diameter, with scattered horizontal branches and irregularly disposed branchlets. It is a decidedly picturesque and quaint tree. The bark of the trunk and main branches is dull grey-brown, rough, and more or less fissured, while that of smaller branches and twigs is pale ash-brown and smooth. Its leathery light-green foliage, closely resembling the fronds of the maidenhair fern in appearance, produce a very distinctive effect, while in autumn it assumes a rich golden tint, which, unfortunately, only lasts a short time. It does well in the London parks, as its thick, tough, leathery leaves are specially capable of resisting the destructive action of atmospheric impurities.

Economic Value.—The timber is yellowish, soft, and brittle ; and as it is a sacred tree in China and Japan, it is not used for economic purposes. The nuts are eaten as a dessert fruit by the Japanese ; but their taste is unpleasant to the European palate, and the sarcous covering has a disagreeable rancid smell. The tree is merely ornamental in Britain.

Soil and Situation.—The Gingko does best on a fresh, loamy, and deep soil, and in a mild and sheltered situation. It only grows well in the warmer parts of Britain.

Cultivation.—Since De Candolle, in 1814, distributed throughout Europe cuttings from a female tree near Geneva, which were grafted on male trees, seed has been produced in many countries ; but as this does not also seem to have been done in Britain, it is rare to find any Gingko-tree producing seed here. Most of our trees have been raised from cuttings or layers. Three varieties known as *macrophylla*, *pendula*, and *variegata* are here in cultivation, and can also be grown from cuttings.

PART III.

SYLVICULTURE

OR THE FORMATION, TENDING, AND RENEWAL OF WOODLAND CROPS

CHAP.

I. THE SCIENTIFIC FOUNDATIONS OF SYLVICULTURE—

The Physiology of Forest-Trees, the Fundamental Facts of Agricultural Chemistry, and the Physical Properties of Soil.

II. THE SYLVICULTURAL CHARACTERISTICS OF BRITISH TIMBER-TREES, AND THE DIFFERENT CLASSES OF WOODLAND CROPS—

Coppice, Copse with Standards, and Highwood.

III. SOWING, NURSERY WORK, AND PLANTING.

IV. THE PLANTING OF WOODLANDS.

V. THE TENDING OF WOODS AND PLANTATIONS—

Weeding and Cleaning, Thinning, Pruning, and Partial Clearance to stimulate Increment.

VI. THE RENEWAL OF WOODLAND CROPS—

The Reproduction of Coppices and Copse-woods, and the Regeneration of Highwoods.

VII. CONCERNING ARBORICULTURE—

Or Planting for Ornament and Shelter.

BRITISH LITERATURE ON SYLVICULTURE
during the last thirty years.

The chief works are: W. H. Ablett, *English Trees and Tree-Planting*, 1880. G. Bagneris, *Manual of Sylviculture*, translated by E. E. Fernandez and A. Smythies, vol. i., 1876; vol. ii., 1882. J. Brown, *The Forester*, 6th edit. (Brown and Nisbet), 1894, vol. i., chapters iv. to vii.; vol. ii., chapters ix. to xi. H. Cleghorn, article on *Sylviculture* in *Encyclopædia Britannica*. C. E. Curtis, *Practical Forestry*, 2nd edit., 1898. A. C. Forbes, *English Estate Forestry*, 1904. J. Grigor, *Arboriculture*, 1868. C. Y. Michie, *The Practice of Forestry*, 1888. J. Nisbet, *British Forest Trees and their Sylvicultural Characteristics and Treatment*, 1893; *Studies in Forestry*, 1894; *Our Forests and Woodlands*, 1900. W. Schlich, *Sylviculture* (in *Manual of Forestry*), 3rd edit., 1904. W. Simpson, *The New Forestry*, 1900. A. D. Webster, *Practical Forestry*, 2nd edit., 1902.

The literature dealing (in the shape of books, chapters of books, articles, and pamphlets) with special parts of Sylviculture and the cultivation of woodland trees is too scattered and voluminous for any useful catalogue to be made of it here. The *Transactions of the Highland and Agricultural Society*, of the *Royal Scottish Arboricultural Society*, and of the *English Arboricultural Society;* the *Journal of the Royal Agricultural Society of England*, and of the *Society of Arts;* the *Reports of the two Committees on Forestry*, published in 1887 and 1903; and the Carpenters' Company's two prize essays on *The Adaptation of Land for Afforestation*, by A. C. Forbes and W. R. Fisher, 1904, all contain much information of interest and value to the student of this branch of Forestry.

CHAPTER I.

THE SCIENTIFIC FOUNDATIONS OF SYLVICULTURE.[1]

THE PHYSIOLOGY OF FOREST-TREES, THE FUNDAMENTAL FACTS OF AGRICULTURAL CHEMISTRY, AND THE PHYSICAL PROPERTIES OF SOIL.

PERHAPS the first and the most necessary sylvicultural fact which the student of Forestry should impress upon his mind is that *there can be no hard-and-fast rules for the growing of timber-crops for profit.* The various factors of soil, climate, exposure, elevation, individual characteristics of trees, market for wood, intentions of proprietor, &c., are all, both individually and collectively, apt to produce specific deviations from general principles; and this fact must always be borne in mind.

A tree is a living organism, constructed mainly of cells and vessels, whose vitality and growth are primarily maintained by the absorption of mineral food through its root-system, and by the ascension of sap to the leaves and its elaboration there, through the assimilation of atmospheric carbonic acid in the foliage, under the action of sun, light, and warmth.

A tree consists of (1) an overground portion forming a *bole* or *stem*, which ramifies into large and small *branches*, *twigs*, and *shoots*, bearing the crown of foliage, and (2) an underground portion with a somewhat similar ramification into *tap-root* or central axis, *side-roots*, *fibrous-roots*, and *suction-rootlets* endowed with one-celled *root-hairs* for imbibing water and soluble food-supplies from the soil. But even in the trees with the most pronounced tap-root (Oak, Larch, Pine) there is nothing corresponding to the formation of a stem before the ramification of the root-system begins. In so far they are shrub-like, owing to the resistance offered by the soil and the necessity existing for them to obtain a large part of their food from the upper earthy layers of soil. The development of the root-system, however, always depends greatly on the physical and chemical conditions of the soil and on the extent (leaf-area) of the crown of foliage.

[1] Students and others specially interested in the subject will find more detailed information than can here conveniently be given concerning the scientific foundations of Forestry in the author's Oxford Lectures on the Principles of Sylviculture, published as *Studies in Forestry* (Clarendon Press, 1894).

A young tree is naturally produced by seed derived from a parent tree. The **seed** germinates under the influence of warmth, moisture, light, and air. By absorbing moisture its tissue becomes softened and stretches; while the water is partly decomposed and partly used in transforming the reserves of starch that are stored up within it and in converting them into dextrin or grape-sugar (when *starch*, $C_6H_{10}O_5$, + *water*, H_2O_1, becomes *glucose* or *grape-sugar*, $C_6H_{12}O_6$) by means of which the vital action of the embryo begins on sufficient warmth being attained.

The embryo lengthens downwards into the earth by the **radicle** or young root, and upwards into the air by the seed-leaves or **cotyledons** (which only remain underground in the case of Oak, Sweet-Chestnut, Walnut, and Hickory, whose seeds can therefore stand a thicker layer of earth than other tree-seeds in nurseries, &c.) Owing to the presence of a slight quantity of iron in their chlorophyll, the seed-leaves become green during the process of decomposition of the carbonic acid absorbed from the earth and the air (when $CO_2 + H_2O$ are transformed into $CH_2O + O_2$, the oxygen being thus set free and breathed out into the atmosphere).

The young root lengthens at its point, and through its suction-rootlets and root-hairs absorbs mineral food dissolved in the soil-moisture. This is conveyed upwards by the cellular tissue, and is exposed in the seed-leaves to the action of light and air. Here water is transpired, and at the same time nourishment is prepared for the maintenance and for the development of the organism by the processes of assimilation of atmospheric carbon and the formation of carbo-hydrates necessary for physiological and structural purposes.

The current of sap keeps rising, chiefly by capillary attraction, from the roots to the growing-point, which lengthens and forms a small shoot. On receiving the sap, the growing-point aërates it and sends it downwards; and from the elaborated sap descending woody matter is formed in the centre of the radicle. The root is thus enabled to ramify while woody matter is also gradually formed within the vessels of the young plant by the deposition of elaborated matter.

Before the growing-point begins to extend, it acquires the rudimentary form of a **leaf**; and as the growing-point lengthens, this develops until the first leaf is completely formed. When fully developed, the first leaf carries on more easily and completely the functions previously performed by the seed-leaves. Assimilation becomes more vigorous, and the elaborated sap passes downwards in larger quantity through the cambial layer of the bark to the root. In its descent it is deposited as cellulose, one part being incorporated with the bark, whilst the rest forms sapwood. And while this lengthening process is taking place, the cellular tissue of the stem is also expanding horizontally to make room for the matter passing into it; so that perpendicular and horizontal development progress simultaneously. Young roots also form at the same time, which increase and ramify by constant gradual increment of the cellular substance at their points; and thus something like a natural balance is maintained between the root-system and the leaf-area for which it has to provide water and mineral food, and on whose assimilative capacity its increment directly depends.[1]

After the production of the first leaf, others successively appear. All are formed like the first, are connected with the stem in the same way, and perform similar functions. At last the growing-point or axis ceases to lengthen for the season, and the old leaves gradually wither and fall off. Meanwhile a new set of leaves, instead of expanding after their formation, remain in their rudimentary state, harden, and fold over one another to protect the delicate point of growth,—or, in other words, become the bracts or scales of a **leaf-bud.** The ascending axis now consists of a shoot with a woody axis, and a distinct pith and bark, the whole assuming a more or less conical shape.

With the spring of the second year, and the return of warm weather, active vegetation recommences. The uppermost buds, and any others formed during the previous year, gradually unfold when the water containing mineral food ascends with increasing temperature in spring; the place of the water transpired and of the sap utilised is instantly filled by continuous supplies from below; the phenomenon called **the flow of the sap** is effected by an impulse being given to the fluids from the summit to the roots; fresh extension is given to the roots by new suction-roots being thrown out; fresh food-supplies are absorbed from the earth, and sent upwards through the soft sapwood formed during the last year; and active vegetation continues with greater or less vigour till autumn. The food-supplies drawn by the roots and transmitted to the leaves as sap are in them subjected to the chemical action of light, and there also take place the processes of assimilation of atmospheric

[1] This natural balance between root-system and foliage also explains the **Physiology of Transplanting.** Plants have no locomotive power, and *the natural requirement* of trees at any age is to remain where they are, without any disturbance of the root-system. Every such disturbance interferes with the normal process of imbibing food-supplies from the soil, and with the transpiratory, assimilative, and constructive processes within the plant. In order to re-establish itself in its new home, the young tree has to expend its starchy reserves secreted for natural purposes; and these reserves cannot be so easily replaced in old trees as in young plants of vigorous growth and active development. Just as with human beings, so too with old trees the power of accommodation to altered circumstances with regard to food-supplies and environment is weaker than in vigorous saplings and poles. The power of even utilising the reserve supplies of nutrients (which in young broad-leaved trees sometimes amount to about 7 per cent of the whole organism) appears to be sometimes denied, when the trees die suddenly; while in the case of those that first of all wilt and then die off, the utilisation of the reserve nutrients may have failed to enable the plants to accommodate themselves to their new environment. It is for the purpose of trying to assist in maintaining the proper balance between the imbibition of food and the elaboration of sap that pruning is required at time of transplanting, except when the plants are so young and small that the roots are only very slightly injured. In transplanting from the nursery to the open ground, the younger the plants are at the time of removal, the less disturbance will they have to overcome. Any one-year's seedling plant can be removed with nearly all its roots entire and uninjured, while a plant that has stood two years in the nursery loses a good many fibrous rootlets during removal; and the damage is greater at three years, and so on for the number of years it may have stood before transplanting takes place. This physiological fact is often overlooked by foresters.

carbon and preparation of carbo-hydrates. Then the elaborated nourishment is returned through the leaf-stalk down through the *cambium*, to be used in forming a new layer of **sapwood** (*alburnum*) on the woody fibrous tissue and of **bark** (*liber*) on the outer protective cuticle. By the end of the year the phenomena of the previous season have been repeated. Ligneous matter is gradually produced throughout the period of active vegetation, and, as the zone deposited in summer is denser than that formed in spring, this gives rise to the appearance of **annual rings** or concentric zones of woody tissue; new shoots and leaf-buds are formed before entering upon the winter period of rest from active vegetation; and the stem has grown in diameter.

During the third year a similar process is repeated, but on a more extensive scale as the plant grows in vigour. More roots and rootlets are formed; food-supplies are absorbed in larger quantities from the soil, and conveyed to the leaves as sap; and the water lost by transpiration is at once replaced by new sap sent up through the soft sapwood next to the bark. New cambial layers are formed, both on the wood and the bark, from elaborated sap in its return downwards from the foliage; whilst the horizontal and the perpendicular developments of cellular tissue are both continued. During the warm summer weather the wood formed has a much more compact character; and another annual ring is added to those formed during the two previous years. And thus for many years the tree continues to grow till it is utilised by felling, or till the natural period sets in when it begins to show the inevitable results of senile decay.

Besides being of essential utility as the *cambium* or medium in which the assimilated nourishment is finally, during its descent from the leaves, elaborated and utilised for structural purposes, the bark also protects the young and tender wood, by guarding it from sunburn, cold, and external accidents. But as the stem and branches grow in girth, the outer layer usually becomes either fissured (Oak, Elm, Birch) or scales freely off (Plane, Sycamore, Pine, Larch) under the pressure from within, although in some trees it preserves a more or less smooth outer surface (Beech, Spruce, Silver Fir).

Leaves are at one and the same time organs of breathing, digestion, and nutrition. They elaborate the crude sap impelled into them from the stem by transpiring and decomposing its water, adding to it carbon during assimilation, and exposing the whole to the action of the air; and they supply the necessary food to the young tissue that extends downwards from them by conveying to this, in the form of elaborated sap, the materials essential for the formation of new wood and bark. If a branch be deprived of leaves for a whole summer, it will either die or will not increase in size perceptibly; and if a tree be pruned, there must be a temporary diminution in the quantity of wood produced.

After the leaves have performed their functions they fall off. This happens at extremely unequal periods in different kinds of trees. In most **deciduous** trees they all wither and fall off by the end of a single season (*e.g.*, Larch, Birch, Ash), though sometimes (*e.g.*, Beech, Oak) the leaves withering in autumn only fall off during the succeeding winter or spring; while in

evergreen trees (*e.g.*, Spruce, Pine, Fir) the leaves neither wither nor fall off at the end of the first season, but persist throughout the winter and till long after the commencement of another year's growth.

The Nutrition and the Growth of Plants are determined partly by physical and climatic circumstances, and partly by chemical conditions. The essential physical factors for plant-life are **Warmth** and **Light**, while the chemical factors are **Oxygen, Carbonic Acid**, **Nitrogen**, and **Water**, together with mineral substance absorbed from the soil in the form of soluble nutrient salts. Where these elementary factors are all combined favourably for the requirements of any individual species of plant, it can thrive well; but where any one factor is unfavourable for the given kind of plant, it will either grow in a poor unsatisfactory manner or else will be unable to grow at all. Hence trees, like all other plants, are subject to what is known in agricultural chemistry as the **Law of the Minimum**, according to which "the total extent of production depends upon whatever essential factor is present *in minimo*,"—no matter however favourable may be the combination of the other factors.

Warmth in soil and atmosphere awakens vegetation in spring and continues it through summer till autumn. Most of our trees begin their annual period of active vegetation when the temperature rises to 6° or 8° C. (43° to 46° Fahr.), but their vegetative energy increases as the temperature rises in summer.

Light is necessary, because it is only through its assistance that the chlorophyll contained in the leaves can decompose water and carbonic acid, and enable them to enter into organic combinations for the elaboration of substances to be used for structural purposes. And various other processes, such as transpiration and the deposition of matter on the cell-walls, are also more or less dependent on the action of light. The amount and the intensity of light necessary before different kinds of trees can carry on assimilation vary greatly, so that the foliage of some is thicker and denser than that of others—*e.g.*, Beech and Spruce as compared with Birch and Larch; but for one and the same kind of tree the vegetative activity due to light varies greatly according to the soil and situation, the leaves and the total leaf-area being larger on favourable localities and smaller on unfavourable. Leaves fully exposed to light contain more chlorophyll, have many more stomata, and are sometimes about thrice as thick as those growing in shade; and even in winter a marked difference in size is noticeable in the buds. If young trees growing in shade be suddenly exposed to the full action of light, their thin leaves cannot always carry out the new work imposed on them, and they often become sickly and predisposed to disease. This explains why, in woods undergoing natural regeneration, the parent trees should only be cleared gradually, although the period for clearance varies greatly according to the kind of tree and the given conditions of the soil and situation. Broad-leaved deciduous trees can accommodate themselves better to rapid transition from shade to light, because of their leaves only lasting for one season; but in evergreen Conifers this accommodative power is least in trees like Spruce and Silver Fir, whose foliage is retained for several years. The poorer the soil, and the nearer it approaches the minimum as to soil-moisture needed for transpiration, the more are trees dependent on a free supply of light for carrying out the assimilative process thoroughly with the limited food-supplies obtainable from the soil. But the total leaf-area decreases in proportion to the food-supplies, and it is therefore all the more important that these should be elaborated very thoroughly, which is only possible with comparatively free exposure of the leaves to sunlight; and this naturally leads to a thin crown of foliage.

Oxygen (O) needed for respiration is always obtainable from the atmosphere, which consists of 20·93 per cent oxygen and 79·04 per cent hydrogen by volume, or 23·28 per cent oxygen and 76·67 per cent hydrogen by weight. But unless the soil is well aerated, the root-system may find difficulty in obtaining sufficient oxygen for its needs. Trees (like Beech) which have numerous and deep-going roots tend to aerate the soil better than shallow-rooted trees like Spruce.

Carbonic Acid (CO_2) from the air is, under the action of sunlight, decomposed by the chlorophyll contained in the leaves, and is there assimilated or prepared for structural purposes in different combinations of carbon. There is never any want of carbon dioxide in the atmosphere, which usually contains it to the extent of 0·03 per cent by volume, and 0·05 per cent by weight.

Insufficient aeration has much the same effect as inundation. The root-system consumes the oxygen within its reach, then the tree sickens and ultimately dies off, although different kinds of trees show great differences in accommodative power.

Nitrogen (N) is required for forming the albuminoid substances so important to the growth of plants. The sources from which timber-crops get the nitrogen they require have not yet been clearly traced. But as most woodland soil only contains small quantities of nitric acid, and some even contain none, their needs must be supplied by the decomposition of **humus** or leaf-mould. In the decomposition of humus nitrogen is transformed into ammonia (NH_3), which again in turn becomes transformed with the aid of a fungus into a **nitric acid** (HNO_3). In order that this fungus (*Bacillus*) may grow, oxygen is necessary; but when there is a deficiency of oxygen in the air within the soil, **nitrous oxide** (N_2O) and free nitrogen are produced. This nitrification is confined to within about 18 in. below the surface. Plants can likewise obtain nitrogen from the atmospheric ammonia contained in rain, dewfall, &c., and also, though only by the symbiotic aid of a fungus (*Bacillus radicicola*), from the free nitrogen of the air, as is the case in the root-nodules or tubercles of leguminous trees like *Robinia*. The Alder and the Sand-Buckthorn (*Hippophaë rhamnoides*) are also endowed with a similar capacity for forming nitrogenous and albuminoid substances, as the tubercles on their roots contain protoplasma filled with fungus germs. Through a symbiotic process quantities of albumen are produced within these root-nodules, and become gradually absorbed by the tree for general use. But so long as nitrogenous food is available in the soil, this symbiotic aid of a *Bacillus* is not invoked.

Water (H_2O) is doubly essential to plants. On the one hand it forms part of their food, and on the other it is needed for dissolving inorganic substances (*nutrient salts*), which can only be absorbed by the root-hairs when held in solution. By far the greatest portion of the water imbibed by the roots is transpired through the leaves, although a certain quantity is used in forming organic tissue, while the hydrogen is entirely obtained from this source.

The quantity of water required by timber crops varies greatly according to the kind of tree, and the soil, climate, and exposure of the land. The smaller the particles of soil and the richer it is in *humus*, the more moisture it can contain. In humid atmosphere the spiracles of the leaves open wider than in dry air, for they can accommodate themselves automatically to atmospheric changes from humid to dry, and *vice versa*, so as to maintain a fairly steady rate of transpiration. For all kinds of timber crops there is, on the one hand, a requisite *minimum* supply of water for healthy growth, and on the other a *maximum* limit beyond which any surplus of soil-moisture is injurious.

Investigations relative to the amount of water transpired by woodland crops were made by von Hönel experimentally in 1879-1881. He found that the evergreen conifers transpire on the average only about one-sixth to one-tenth of the quantity of water that is evaporated by broad-leaved trees, and that even for Beechwoods, as in the dry climate of Central Europe, a summer rainfall of 12 in. meets their requirements in water.

Of greater practical interest, however, are Ebermayer's investigations regarding the **relative transpiration** or **relative requirements as to soil-moisture** of different kinds of forest-trees, by determining the percentage of water contained in fresh leaves. The results he obtained, and which correspond with practical experience, were as follows, per **unit of foliage** :—

Broad-leaved Trees.				Coniferous Trees.	
	Percentage of water.		Percentage of water.		Percentage of water.
Italian Poplar	70	Birch	61	Cembran Pine	64
Horse-Chestnut	65	Mountain Ash	61	Black Pines	63
Ash	65	Sycamore	61	Larch	62
Common Alder	64	Willows (in general)	60	Weymouth Pine	61
Acacia (*Robinia*)	64	Maple	59	Scots Pine	59
Oak	63	Aspen	59	Spruce	59
White Alder	63	Beech	57	Mountain Pine	57
Elm	63	Hornbeam	57	Silver Fir	55
Lime	63	Silver Poplar	55		

This classification may in some respects seem inconsistent with practical experience; but it must be borne in mind that it only applies per **unit of foliage**, and that, thanks to their deep-reaching roots, trees like Oak, Beech, Larch, and Pine can draw constant supplies of moisture from the subsoil, while Spruce can only obtain sufficient when the soil is already so moist that a fair proportion of the rainfall is retained near the surface in the layer of soil permeated by its shallow root-system. It will be noted that long-leaved Pines all transpire more freely than the short-leaved Spruce and Silver Fir. But in all Conifers (except the Larch) the thick, hard, and resinous epidermis limits the rate of transpiration considerably. And as transpiration is slow, the upward movement of sap is also slower than in broad-leaved deciduous trees.

The Indispensable Mineral Ingredients in the food of plants include potash, lime, magnesia, iron, sulphur, and phosphorus, as well as nitrogen; while silica, soda, chlorine, manganese, and occasionally alumina, are also found in the ash of timber (after carbon, hydrogen, oxygen, and nitrogen have been eliminated by combustion), though they can hardly be considered indispensable constituents. But the different physiological uses of these mineral substances have not yet been clearly determined.

Potash (K_2O) is found chiefly in the leaves and the younger parts concerned with the active processes of assimilation and of forming starch and carbo-hydrates. **Lime** (CaO), indispensable for all chlorophyll plants (but not fungi), is also supposed to be of use in forming and distributing the carbo-hydrates, and in forming insoluble combinations with oxalic and other poisonous acids thus rendered harmless to the tender tissues of the plant. Lime is the most important of the inorganic food-stuffs as regards the growth of timber-crops, and nearly all our trees thrive best when there is a fair amount of lime in the soil. Beech and Black Pines show a very decided preference for soil rich in lime, but even a small percentage of carbonate of lime interferes with the growth of Sweet-Chestnut and Maritime Pine. **Magnesia** (MgO) is used in forming albuminoids, and is supposed to have an important influence in the production of seed, although it is only absorbed from the soil in very small quantities. **Iron** (FeO and Fe_2O_3) is requisite, though also only in small quantities, for the formation of chlorophyll necessary for the work of assimilation carried on in the foliage with the aid of sunlight. **Sulphur,** taken up in the form of sulphates—salts containing sulphuric acid (H_2SO_4)[1]—is likewise used in forming albuminoids, for which also **Phosphorus,** in the form of phosphoric acid (P_2O_5), is an essential requisite. The presence of **Chlorine** (Cl) and of **Soda** (Na) is most pronounced in plants growing near the sea-coast and on brackish soil; and though their specific action is not yet clearly understood, they are supposed to assist in the movement of carbo-hydrates within the plant.

For the practical purposes of Forestry the most important soil-nutrients are water, then lime, potash, and phosphoric acid; and the chief nitrogenous compounds are nitrates and ammoniacal salts or certain nitrogenous organic constituents in **humus.** On soil which offers to woodland crops richer supplies of food than can be thoroughly assimilated by them, deposits of mineral substances take place within the plants in excess of their physiological requirements. Wherever this occurs in any excessive degree, it leads to a condition at once predisposing to disease and, at the same time, capable of offering least resistance to any attacks that may be made by fungous parasites or by insect enemies (*Studies in Forestry*, p. 81).

That the different kinds of trees vary greatly with regard to the mineral food they require, can easily be proved by analysis of the ash after non-mineral portions of their tissue (formed by carbon, hydrogen, oxygen, and nitrogen) have been eliminated by combustion. The **leaves** and **cambium,** the younger parts of the organism actively engaged in assimilation and secretion, give more ash, and are richer in salts of potash, phosphates, and nitrogenous compounds than the older portions forming the **sapwood,** and the hard inert tissue forming the **heartwood** of the stem. The leaves contain the richest deposits of mineral matter, while the bark contains more than the wood, and the younger portions of the tree contain more than the older portions. Thick fleshy bark contains larger mineral deposits than are stored up in rough and rugged bark. When the foliage of deciduous trees is about to die in autumn, the more important mineral nutrients (potash, phosphoric acid, magnesia, and lime) are conveyed and stored up in the twigs and other active parts of the organism until required again for active vegetation in the following spring.

The total percentage of mineral ash in the timber of broad-leaved trees usually ranges between 0·3 and 0·4 per cent of the dry substance of the wood (although it is 0·5 per cent in the *Robinia*); but in Birch and most Conifers it varies from only about 0·17 to 0·27 per cent. The heartwood of old stems, besides containing less ash than the sapwood, is also comparatively devoid of albuminoid substances; consequently it is more durable, because less affected by the decomposing influence of alternating damp and heat, and less exposed to attacks of saprophytic fungi and of insects.

Seeing that most of the mineral matter is deposited in the leaves of trees, woodland crops must make the greatest demands for mineral food just when their foliage becomes densest; and such period is about the twentieth to

[1] Sulphurous acid (SO_2) is a common impurity in the air. It is carried by rain into the soil, where it forms sulphuric acid ($SO_2 + H_2O = H_2SO_4$).

thirtieth year for Scots Pine, the thirtieth to fortieth year for Spruce, and the fortieth to fiftieth year for Oak and Beech, on the better classes of soil, and about ten years or so later on poorer soil. But on the fall of the leaf most of the mineral salts absorbed from the soil are finally returned to it, leaving only the comparatively small proportion deposited in the timber as representing the permanent withdrawal of soluble minerals. According to Ebermayer's investigations, the total amount withdrawn and stored up in the timber varies from about 12 lb. per acre per annum (Birch and Scots Pine) to about 30 lb. or over (Oak and Beech), distributed as follows:—

Lime	from 4 lb. in Birch	to 20 lb. in Beech	per acre per annum.
Potash	" 2 " Alder and Scots Pine	" 10 " Silver Fir	" "
Phosphoric acid	" $\frac{4}{5}$ " Scots Pine	" $4\frac{1}{3}$ " Beech	" "

Ebermayer also made analyses of dried foliage to ascertain the amount of mineral ash it contained, with the following results **per unit of foliage**:—

Broad-leaved Trees.				Coniferous Trees.	
	Per cent.		Per cent.		Per cent.
Ash	7·61	Aspen . .	5·15	Silver Fir . .	2·93
Italian Poplar .	7·04	Willow . .	5·11	Cembran Pine .	2·78
Elm	6·92	Oak . . .	5·10	Larch . . .	2·54
Lime	6·55	Silver Poplar .	4·69	Spruce . . .	2·39
Mountain Ash .	6·20	Hornbeam . .	4·20	Weymouth Pine .	2·35
Acacia (*Robinia*) .	6·16	Beech . .	4·02	Scots Pine . .	2·28
Horse-Chestnut .	6·03	White Alder .	3·92	Black Pines . .	1·82
Sycamore . .	5·33	Birch . . .	3·90	Mountain Pine .	1·36
Maple . . .	5·21	Common Alder .	3·69		

It will thus be seen that, in a general way, the trees with strongest transpiration also withdraw the largest supplies of mineral food from the soil; and this corresponds very fairly with actual experience. But these results are only **per unit of foliage**; and as yet no exact data have been collected regarding the total amount of mineral food annually withdrawn from the soil.

According to Weber (*Die Aufgaben der Forstwirthschaft* (in Lorey's *Handbuch*), 1903, p. 81), the analyses of different woods show that timber consists, on a rough average, of 50 per cent carbon, 42 per cent oxygen, 6 per cent hydrogen, 1 per cent nitrogen, and 1 per cent ash only, while the whole demand made for mineral food is, roughly speaking, only about one-half of the average quantity withdrawn by agricultural crops, according to Ebermayer's investigations (*Physiologische Chemie der Pflanzen*, 1882, vol. i. p. 761).

Average of	Total quantity of ash.	Lime (CaO).	Potash (K_2O).	Silica (SiO_2).	Phosphoric anhydride (P_2O_5).	Magnesia (MgO).	Sulphuric anhydride (SO_3).	Other constituents.
Mixed agricultural crops	235	43	78	37	28	17	11	21
Woodlands (timber and leaves) . .	126	62	11	29	8	10	3	3
Woodlands (timber only)	19	9	4	1·6	1·4	2	0·4	0·6

The Chemical Composition of Soil is not usually of the first importance to woodlands, because most kinds of soil contain the essential mineral food of trees in sufficient quantity to maintain tree-crops of any kind. But there is not always sufficient soil-moisture to hold them in solution, so that they are not available for absorption by the root-system. On the other hand, a rich fertile soil, furnishing copious food-supplies in excess of what can be assimilated thoroughly, will produce large quantities of timber, but it will be soft, spongy, and little able to resist the attacks of parasitic fungi while standing, or of saprophytic fungi after felling and conversion.

Soil is largely made up of **Salts**, with oxides and sometimes chlorides. The **Salts** are mostly silicates (often combined with water), carbonates, and sulphates; while the phosphates, so important for plant-life, only occur occasionally. In the formation of these **Salts**, the most important of the **Acids** are silica (SiO_2), carbonic acid (CO_2) sulphuric anhydride or sulphur trioxide (SO_3) and phosphoric anhydride or phosphorus pentoxide (P_2O_5); whilst the chief **Bases** are potash (K_2O), soda (Na_2O), lime or calcium oxide (CaO), magnesia or magnesium oxide (MgO), ferrous oxide (FeO), sesquioxide of iron or ferric oxide (Fe_2O_3), alumina (Al_2O_3), and manganese dioxide (MnO_2). The **Silicates** comprise quartz, serpentine, talc, felspars, mica, hornblende, augite, and chlorite; the **Carbonates** include carbonate of lime, chalk, and dolomite; to the **Sulphates** belong anhydrite and gypsum or calcium sulphate. When the water of crystallisation in many salts composing rocks becomes heated and driven off, the salt crumbles into powder; and, at the same time, all rocks, being porous, are pervious to water, which not only dissolves certain salts, and holds them in solution ready for absorption by the roots of plants, but also effects transformations in many chemical compounds. Thus water impregnated with carbonic acid dissolves silicates containing alkaline earths and ferrous oxide, as also carbonate of lime ($CaCO_3$) and ferrous carbonate ($FeCO_3$) which are easily soluble in it, whilst magnesium carbonate ($MgCO_3$) is much less so. The products of the decomposition of rocks are mostly alkalies in combination with silica and carbonic acid, together with carbonate of lime, magnesia, and ferrous oxide, whilst soluble sulphate of lime is also found in most soils; but as these salts act and react on each other, many various compounds are formed.

Rocks of complicated structure decompose most rapidly, as, for instance, those rich in felspars, or in compounds of iron, in contrast with silicious slate or quartz-rock; pure limestone decomposes slowly, but this difficulty diminishes with any increase of alumina and iron. Sandstones and conglomerates decompose in proportion to the cementing matter they contain, and to the degree in which this is affected by moisture. Fine-grained and massive rocks are less apt to fissure and crumble than coarse-grained stones or slaty beds, as they afford fewer points of attack to water, mosses, herbage, and other disintegrating influences.

Vegetation plays an important part in the formation of earth, not only by helping to fissure and cleave the soil and subsoil, so as to enable water to effect an entrance, but also by reason of the decomposition of the organic *débris* of foliage, dead wood, &c., and the formation of **humus** or mould, which takes place under the combined action of oxygen, moisture, and a minimum warmth of 52° Fahr. When humification takes place only under partial exposure to the atmosphere, humic and similar acids are formed, and saprophytic fungi aid in the work of decomposition, by attacking the albuminoid substances first of all. These acids (humic, ulmic, geic, &c.) have a strong affinity for ammonia (NH_3), which is itself essential to the nourishment of trees (*Studies in Forestry*, p. 94).

The classification of Soil according to its geological origin is misleading. The same kind of rock does not always yield similar soil; the fertility of the soil depends on the extent of its decomposition; and some of the lighter particles of clay are more easily washed away than the heavier sand. For practical purposes the best classification is into—

Sandy Soil, containing 75 per cent or more of disintegrated sand. It occurs as sand-drifts, or is the product of the decomposition of sandstones. This includes *sand* and *loamy sand*.

Loamy Soil, always tinged with iron, containing 60 to 70 per cent of fine sand and silicious dust, the rest being chiefly made up of clay with less than 5 per cent of lime, and an almost constant quantity (5 per cent) of hydrated ferric oxide. This includes *loam* and *sandy loam*.

Clayey Soil, containing 50 per cent or more of clay. It is mostly formed from rocks rich in felspars, augite, and hornblende, of sandstones and conglomerates cemented with clayey cohesive substance, and of the clayey layers and bands throughout sandstones and lime formations. This includes *clay* and *loamy clay*.

Limy Soil, containing not less than 10 per cent of carbonate of lime. It is produced chiefly by limestones, and also by other rocks containing lime felspar (labradorite); but it often happens that limestone rocks produce a loamy rather than a limy soil on decomposition. This class includes *lime*, *clayey lime*, *loamy lime*, and *marl*.

Sandy soil feels coarse and gritty when slightly moistened. Sand becomes easily heated or cooled, and has a poor capacity for retaining moisture and nutrient salts in solution. It is therefore an inferior soil, on which trees need a large growing-space to obtain the requisite food-supply, fail to maintain good leaf-canopy, soon culminate in increment, produce little seed, and are otherwise weak in reproductive capacity. Easily warmed by day, it encourages early germination of seed, early movement of sap, and early flushing of foliage in spring; but as it cools rapidly at night, the young tissues are thereby exposed to danger from late frost.

Clayey soil sticks if touched with the tongue, and smells of ammonia if breathed upon; rubbed between thumb and forefinger it has a fatty feel; and it takes a polish if rubbed with the thumb-nail. It is usually tinged with iron, and may be grey, yellow, or brownish-red in colour. It is tenacious, weakly hygroscopic, and impermeable to moisture, but when once saturated is very retentive of moisture. It is a cold soil and apt to become water-logged. Admixture of sand, iron, lime, or marl tends to modify these characteristics. As soluble nutrient salts are not easily washed out of the soil, clay contains comparatively large food-supplies within a small space: tree-crops on clay have a better leaf-canopy than on sandy soil. Unless the subsoil be permeable or there be good natural drainage, such land soon turns marshy. Owing to the low conductivity of heat on clayey soil, the awakening of vegetation is late in spring.

Limy soil effervesces if nitric acid be dropped on it. Marl and true lime are included in this class; but in marl the lime is equally admixed throughout each particle of the soil, whilst in true lime it is not. By admixture such soil becomes *sandy*, *loamy*, *clayey*, or *stony* lime or marl. Limy soil is apt to be shallow in depth; but woods with good canopy often show fine growth of timber. Their consistency gives a favourable distribution of soil-moisture, even on steep hillsides, so that the tree-roots spread and easily obtain the necessary food-supplies. But when limy soil has deteriorated through insolation following on interruption of the leaf-canopy, or indiscretion in laying bare the soil by clear-felling, the soil-moisture soon evaporates, the finer earthy particles are washed away, the soil becomes shallow, dry, and hot, and considerably less timber is produced. The successful replantation of such deteriorated limy soil is one of the most difficult tasks. On limy soil a layer of *humus* and dead leaves is necessary for maintaining anything like the productivity commensurate with its fertility, so that timber-crops should here only be renewed by natural regeneration. Limy soil properly protected against insolation is favourable to the growth of coppice.

Loamy soil has more resemblance to clay than to sand, but it neither feels fatty when rubbed between finger and thumb, nor takes any definite polish when burnished with the finger-nail. It is a mild soil, whose main characteristic depends greatly on the amount of sand, clay, or lime contained in it. Though the absorption and retention of soil-moisture is greatly dependent on the nature of the subsoil, loamy soil is undoubtedly favourable to the growth of nearly all of the more valuable broad-leaved trees (Oak, Beech, Elm, Maple and Sycamore, Sweet-Chestnut, &c.) But land of this class is generally suitable for agriculture.

As the fertility or productive capacity of soil is neither dependent on, nor mainly proportional to, the mineral richness of the rocks from whose decomposition they are formed, no hard-and-fast classification as to their mineral strength is possible. It can only be said that, in general, clayey soil is slow in forming *humus* and giving nutrients to tree-life, whereas limy soil decomposes organic matter rapidly and stimulates tree-growth, and that intermediate positions between these two groups are occupied by sandy and loamy soil, except when the sand is deficient in soil-moisture.

Soil is always improved by an admixture of **humus** to a moderate extent. It not only adds depth to the land, but, being of a strongly hygroscopic nature, also condenses and retains atmospheric moisture; whilst, owing to its low conductivity, it protects the soil against evaporation. It is also directly active in aiding the continuous decomposition of the soil by means of the carbonic acid set free during the process of decomposition. It modifies all extremes of physical properties in soil; and though not an absolute necessity for the production of woodland crops, yet it is of inestimable value in stimulating the action of soil, no matter of what geognostic origin. Indeed, as Gayer remarks (*Waldbau*, 1889, p. 27), there can be little doubt that "*humus forms the most important factor relative to tree-growth, and is a priceless treasure as regards the production of woodland crops.*" And the beneficial influence it exerts on the aeration of soil is by no means its least important quality (*Studies in Forestry*, p. 101).

The Physical Properties of Soil determine, far more than the chemical or mineral composition, its suitability for producing profitable timber-crops; and all the physical properties, whose variations are innumerable, act and react on each other in determining the quality of any given land. These physical properties[1] include (1) **Cohesiveness,** (2) **Soil-moisture,** (3) **Soil-temperature,** and (4) **Depth.**

(1) **Cohesiveness or Tenacity** is the resistance offered by any soil to separation or disintegration of its particles. This property is important in relation to air, moisture, and warmth, and on it also depends the resistance to be overcome by roots in penetrating the soil and ramifying throughout it.

Clay soil has the greatest tenacity, *sand* the least; *lime* is more like clay, and *loam* more like sand. An admixture of *humus* makes clay and lime less tenacious, and stiffens loam and sand. The liability of soil to expand after rainfall and to shrink during drought is practically proportional to its tenacity. Soil may be distinguished as—

Heavy, stiff, or tenacious (clay and clayey loam, lime, and marl); *mild* (loam, sandy loam, and loamy lime); *light* (loamy sand and sandy marl); *loose* (the poorer sandy soil); *shifting* (sand-drifts and dunes).

A light soil with a favourable distribution of moisture, humus, and mineral nutrients produces most rootlets and foliage, and consequently most timber. The

[1] The subject is very fully dealt with from the agricultural point of view by R. Warington, F.R.S., *Lectures on the Physical Properties of Soil*, 1900.

best growth in height and the largest yield in cubic contents are attained on alluvial deposits having finely pulverised particles. But when light soil is deficient in moisture, plants have difficulty in establishing themselves and obtaining sufficient water for transpiration.

(2) **Soil-moisture** is a matter of the first importance for the growth of timber-crops. Trees cannot grow without water, because only soluble nutrient salts can be imbibed by the suction-roots, and neither transpiration nor assimilation could possibly take place in the leaves without it. Moisture makes stiff soil milder and loose soil stiffer, thus helping to regulate the soil-temperature. Excess of soil-moisture retards the process of decomposition of soil and of humus, and leads to the formation of injurious acids, and through them to the formation of marshes. It interferes with aeration of the soil, so that seeds and roots suffer and become easily infected with fungous diseases. Through its poor conductivity and the amount of heat necessary for raising its temperature, much soil-moisture both retards vegetative activity and increases danger from frost. According to the amount of moisture contained, soil is called *wet*, *moist*, *fresh*, *dry*, or *arid*.

Most trees thrive best on a fresh soil, though Willow, Poplar, Ash, Elm, and Hornbeam prefer a moist, and the Alder even a wet, soil; but stagnating moisture is never favourable to tree-growth. A dry soil is not demanded by any of our trees; but Birch, Rowan, Aspen, Black Pines, Scots Pine in general, and Beech on limy soil, can accommodate themselves to less soil-moisture than other trees. The general quality of a soil for producing profitable timber-crops is indicated by the weeds that grow upon it.

1. A *wet soil* is indicated by moss, cranberry, bell-heather, marsh cistus, cotton-grass, sedge, and rushes.
2. A *fresh, humose soil* is shown by raspberry, bramble, foxglove, willow-herb, nightshade, balsam, nettles, vetch, ferns, clover, and broad-leaved grasses.
3. A *dry* or a *sandy soil* bears heather, whortleberry, bracken, furze, broom, and ragwort.

(3) **Soil-temperature** varies with changes in atmospheric temperature, but such variations depend far more on the quantity of moisture and the colour of the soil than on its specific warmth. Clay soil is retentive, cold, and inactive; but once heated, it only cools gradually. Sandy or gravelly soil is easily warmed and stimulated, but cools again rapidly, and in damp localities this increases the danger from frost. Diurnal variations of temperature are in Britain obliterated at a depth of about 20 in. below the surface, weekly differences at about 40 in., and monthly variations at about $6\frac{1}{2}$ ft.

(4) **Depth** is the extent to which soil is decomposed. The finest earth is to be found near the surface, where the soil shows the greatest effects due to various disintegrating causes or "*weathering*." The lower one digs below the surface, the larger will be the stones and breccia found, until at last a **subsoil** is reached that is practically unaffected by the decomposing agents, and which may, or may not, be of different geological origin from the soil above it. A soil easily penetrable by tree-roots for a considerable distance below the surface is called *deep*, and when the available layer of earth is thin it is called *shallow*. In this respect soil may be classed as *very deep*, *deep*, *medium*, *shallow*, and *very shallow*.

For trees like Oak, Sweet-Chestnut, Larch, and Pines, which form a deep-going tap-root, depth of soil is very important, because if the root-system cannot develop normally, the growth in height soon becomes sluggish. Trees with fairly deep-going root-systems, like Beech, Ash, Elm, Maple, and Sycamore, Silver Fir, and Douglas Fir, and even comparatively shallow-rooting kinds like Birch, Aspen, and Spruce, all thrive better on deep soil (generally containing better supplies of soil-moisture and of food in soluble form) than on shallow soil. Deep soil is much less affected by drought or heavy rainfall than shallow soil ; and the disadvantages of a wet climate are intensified on shallow land when the subsoil consists of horizontal layers of stiff clay or impermeable ferruginous deposits like moorpan or limonite.

In Britain good deep soil can generally be used to more advantage for field-crops than for growing timber.

The Influence of Situation, including the combination of all conditions affecting **atmospheric temperature** and **moisture**, is comprised in the term **climate**. Some trees require a degree of warmth that does not suit others, which can thrive with, and are often benefited by, a winter temperature so low as to extinguish the vitality of the former. Some (*e.g.*, Spruce) transpire freely through the foliage, and need rather a damp soil and atmosphere, whilst others (*e.g.*, Larch and Scots Pine) prefer drier conditions.

Atmospheric temperature is mainly dependent on distance from the equatorial line, although the distribution of land and water, lofty mountain-ranges, &c., always exert a more or less modifying influence. Owing to our insular position and to the influence of the Gulf Stream, we have no such extremes of heat and cold as occur in continental countries of about the same latitude either in Europe, Asia, or America. One effect of these local modifying influences is that there are no clearly defined zones of woodland trees.

Near the snow limit on mountains, and near the polar regions, there are no woodlands. This may perhaps not be entirely due to the low temperature in winter, but may be partly due to transpiration being induced in the leaves of the evergreen Conifers (which reach to the highest latitudes and elevations) on bright sunny days, while the soil is still frost-bound and unable to furnish moisture to replace that evaporated ; and if the winters are long, dry, and sunny, the trees will naturally droop and die.

Although trees, even when young, suffer comparatively little from severe cold, yet late frost in spring may injure young leaves and shoots, and early frost in autumn may damage shoots before they have hardened, such danger being always greatest in low-lying hollows where there are no free currents of air. Ash, Acacia, Sweet-Chestnut, and Beech are most sensitive to frost ; Lime, Hornbeam, Elm, Birch, Larch, Aspen, Sallow, and Austrian, Corsican, and Scots Pines, are decidedly hardy ; whilst Oak, Maple, Sycamore, Spruce, Silver Fir, Douglas Fir, Willow, Poplar, and Alder occupy an intermediate position.

Elm, Sweet-Chestnut, pedunculate Oak, and Black Pines require more warmth than any of our other forest-trees, while Larch and Cembran and Mountain Pines can do with least. The amount of warmth during the period of active vegetation usually determines whether or not any given species of tree can thrive and regenerate itself naturally in any given locality. For example, it is seldom warm enough for the English Elm to form good seed in our climate ; and if it were not for its power of throwing up suckers, it could never have maintained itself in British woods.

Light is also of great importance to the welfare of woodland crops. The demands of different trees as to light, and their capacity for enduring shade, explain many of the phenomena noticeable in the growing of timber for profit (see p. 325).

The **Relative Humidity** of the air is governed by the atmospheric temperature, because the saturation-point is reached much sooner when the temperature of the air is low than when it is high. But no rule obtains regarding the relative humidity of the air, as local circumstances mainly determine the amount of moisture available for evaporation. In Britain, the south and west winds coming from over the Atlantic have a high relative humidity, whilst the east winds coming from across Central Europe are comparatively dry.

The **Aspect, or Exposure** towards one or other of the cardinal points, has great influence on the soil-temperature and the amount of soil-moisture retained. Warm southern and south-western aspects are usually much drier and more apt to become exhausted of moisture and deteriorated than the cooler and damper northern and north-eastern exposures, where vegetation is later in awakening in spring, the assimilative process is altogether less active, and *humus* takes longer to decompose. But on high mountain-ranges trees will ascend to a higher level on the warm southern side than on the colder north side. Eastern exposures suffer most from late frost, while western and south-western aspects are mainly exposed to windfall and breakage from heavy storms accompanied by rain.

The **Slope or Gradient** influences tree-growth, because the steeper a hillside the greater is the chance of the surface-soil being washed away. Land with a slope of over 20° to 25° is too steep for profitable agricultural use, but up to about 45° it can still be made to produce timber-crops, though not of the best quality. And the opportunities which rain-water has of percolating into the lower layers decrease as the steepness of the slope increases.

The **Configuration of the Soil and of the surrounding Country** also exerts influence on the woodlands. Near the base of hills the soil is generally deeper, richer, and more productive than on the slopes or ridges ; but danger from frost is greater in hollow and low-lying tracts than where there is a free movement of air.

Soil - Preparation before Planting.—Before waste land is first brought under timber, the soil usually requires to be specially prepared to some greater or less extent. Such soil-preparation is of even greater importance for the germination of seeds and the thriving of young seedlings when woods are being regenerated naturally, or are produced artificially by sowing, than when plantations are being formed with transplants that have already passed through the dangers incidental to their earliest life-period.

A light, porous, and permeable soil is more favourable to the growth of young seedlings than a heavy and binding soil. In the former there is better aeration, and the atmospheric precipitations (dew, rain, melting snow) can be absorbed more freely, while in the latter rain-water is apt to flow from the hillsides without percolating into the soil, or to collect as stagnating moisture on level tracts. And the shallower the soil, the greater is the danger of such inconveniences, more especially if the subsoil be unfavourable to tree-growth.

In woodlands forming close canopy the tendency to "caking" of the surface-soil, through exposure to the deteriorating influence of sun and wind, is naturally obviated by the annual fall of foliage. This decomposes into *humus*, and is then capable of ameliorating the physical properties and enhancing the general productivity of the soil, unless abnormally wet.

On land that has already been under a timber-crop, the roots left in the ground, as not being worth extracting, gradually decompose and form veins of humose soil, tending to better aeration and to more favourable absorption and retention of rain-water and melted snow. But on bare hillsides cleared of woodland covering the case is different. Here there is either little or no humose matter to improve the physical conditions of the soil and stimulate its productivity, or else it may be a dry dusty humus of heather - mould and lichens, which is more likely to be injurious than advantageous to timber crops. Both of these conditions are unfavourable to woodlands, because they fail to assist in procuring the desirable degree of absorption, retention, and diffusion of soil-moisture. Hence a certain amount of soil-preparation is usually necessary to make at least the upper layer of soil more porous and permeable in the case of stiff or binding land; whilst for sieve-like sandy soil the only practicable method is to encourage woodland growth of any kind that seems able to thrive, and then the land will naturally and gradually improve through the humus formed from the fall of the leaf.

When strong loamy or argillaceous soil cakes or sets on the surface, and is exposed to direct insolation and the drying action of east winds, it parts with its moisture, owing to capillary attraction, to a far greater extent than soil that has a loose upper layer; for in the latter instance the aqueous precipitations not only percolate downwards more easily, but the capillary action is also checked by the greater size of the interstices between the individual grains of earth.

Soil-preparation may consist of (1) superficial drainage, (2) improving the physical conditions of the soil and subsoil (including subsoil drainage), and (3) clearing and burning the surface-growth of weeds (heath, heather, furze, &c.) Superficial and subsoil drainage have often to be carried out considerably in advance of planting—*e.g.*, in such cases as moorpan, where the action of frost is necessary for thorough disintegration of the impermeable stratum of sand and heather-mould (caked by means of 2 to 5 per cent of ferric oxide). And, of course, the depth to which the preparation must extend depends on the density, tenacity, and wetness of the soil.

Soil-preparation consists in making stiff or impervious land more porous and permeable, and in binding excessively light soil (like shifting sand). The benefits of breaking up and aerating stiff soil were well known and appreciated three hundred years ago, for in the time of James I. among the orders given for the planting of Oak in the New Forest there was a specific direction about "*the ploughing of the land for the raising of new woods*" (see p. 21).

Continental Investigations on this point have resulted in the following conclusions regarding the effect of soil-preparation on different kinds of forest land:[1]—

1. **Stony Soil.**—Soil-preparation on land of this class usually does more harm than good. The finer earthy particles are apt to be washed away, and the soil becomes so loose that the roots of the young plants find difficulty in establishing themselves. In sylvicultural operations under these circumstances, soil-preparation should therefore either be avoided, or else confined to the collection of pockets of good earth for receiving the plants; and when the planting is being carried out, the soil should be partially protected by laying small stones over the earth.

2. **Sandy Soil.**—Soil-preparation is generally advantageous on sandy soil; and the deeper it is carried out the better. The capacity for retaining moisture is usually thereby increased; and the admixture of deeper soil which comes partially to the top favours productivity, as the top-layers generally contain less mineral food than the lower strata, owing to the scouring effect of heavy rainfall.

[1] Ramann, *Forstliche Bodenkunde und Standortslehre*, 1893, p. 425, and article on *Forstliche Standortslehre* in Lorey's *Handbuch der Forstwissenschaften*, 2nd edit., 1903, vol. i. pp. 103-198. See also R. Warington, *op. cit.*

3. **Loamy Soil.**—Soil-preparation should hardly extend below the upper layer which contains the earthy ingredients, or in which, at any rate, the soluble nutrients are least plentiful. If it extends to the more argillaceous layers, the earthy nature of the surface-soil may be quite destroyed, and then much more harm than good may ultimately result.

4. **Clayey Soil.**—Soil-preparation should be confined only to superficial work with the pick; any deeper operations are injurious.

5. **Limy Soil.**—Shallow limy soil is mostly stony and poor in earthy ingredients; hence soil-preparation is, as a rule, of little practical advantage. Deep limy soil corresponds very much with clay, so that the same rule may be applied.

6. **Humose Soil.**—Light soil is made still more porous by being opened up. Hence any soil-preparation on humose sand in a damp locality can only be disadvantageous, and may materially increase the danger of the soil being lifted by frost. But when the preparation of land of this description extends to bringing up the layers of pure sand to the surface and imbedding the humose surface-soil, then it is decidedly advantageous.

7. **Soil composed of different Layers.**—Soil-preparation is very necessary in all cases where an impervious or impermeable layer divides the surface-soil from the subsoil (as in moorpan and limonite). But insufficient preparation is sometimes more injurious than no attempt at all to improve the productivity of the soil. In carrying out the operations, no general rule can be laid down, as the concrete conditions of each case must be taken into consideration.

8. **Soil with Wet Subsoil.**—Unless at the same time accompanied by drainage, any soil-preparation in such cases remains without favourable results. Capillary attraction is strongest in the vicinity of the water-level; and by loosening the soil, the level of the injurious superfluity of moisture is often practically raised. This drawback is, however, only felt when the water-level in the soil is comparatively high; for the lower the water-line, the more beneficial soil-preparation will prove, especially on sandy soil.

Advantages of Drainage.[1]—On wet soil drainage is the best way of securing favourable conditions for growing tree-crops, and it is only thus that they can be properly utilised. Drainage not only *directly* removes injurious superfluity of moisture, but also *indirectly* effects aeration or circulation of oxygen throughout the soil. Plants could not live without water, but excess of moisture injures the root-system. Owing to the latent power of water, wet undrained land remains so cold and inactive as greatly to limit imbibition by the suction-roots.

Soil-temperature is dependent on various factors, of which soil-moisture is the chief. The high capacity of water for absorbing heat, and the heat evolved during evaporation, reduce the temperature. Humus acts in the same way; it influences the soil in respect to the absorption, retention, and diffusion of moistnre. Moist humose soil is therefore slow in having its temperature raised when mild weather comes in spring; but on the other hand, it is warmer during summer, and more particularly during autumn, than soil containing less moisture. A practical difference is therefore made between *mild* and *cold* soil. To the *cold* and *wet* class belong humose soil (*e.g.*, peat-hags), clay and loamy soil; while under *mild* soil is comprised all land of a sandy nature (Ramann, *op. cit.*, p. 94).

Another effect of drainage is practically to increase the depth to which tree-roots can descend for their supply of food. The deeper the drainage the greater will be the permeability of the soil and its capacity for absorbing

[1] Strictly speaking, the word **Drainage** means only the drawing off of a surplus of water from the soil; and the aeration and changes with regard to conductivity of heat, and to other physical properties, are consequences of the operation not included in the idea of drainage at all. But all these main objects are comprised within the term **Soil-preparation.** To speak of draining a dry soil would be absurd; yet dry land often needs preparation before it can be planted with any chance of profit.

heat, and it will the more easily supply the roots of trees with their normal requirements as to water and mineral food.

Soil that is merely fresh is in general best suited for timber-crops—except in special cases like Alder, some Willows and Poplars, &c., requiring a large amount of water for transpiration. Cold soil only responds gradually to the change of temperature in spring, and vegetation is therefore not likely to become awakened so early as to be killed by late frost succeeding a few days' warm weather; nor is it apt to become overheated during summer; and its store of accumulated heat is only gradually given off in autumn, so that the young woody tissue in shoots and twigs can mature thoroughly before early frost comes in late autumn.

Drainage of Woodlands[1] is necessarily very different from agricultural drainage, because of the difference in the size of the roots of the plants grown.

Field drains are made with pipes sunk into the ground, both to protect them from accident and to give up all the land to the farm-crop. Woodland drains are left open, both because such are cheaper, and because they would otherwise soon become inoperative by being choked with tree-roots.

For leading off water, ditches are dug; these are the drains of the forester. Open ditches are the rule, although covered drains have the greater advantages of incurring no loss of useful area, of not interfering with traffic, and of being less active in their operation, especially when filled with brushwood. Wide drains are needed here and there at culverts; but any extensive and regular system of thorough *drainage*, such as is applied with excellent results to agriculture, can hardly be undertaken by the forester except on a small scale (in nurseries, &c.) His field, the forest, is too vast; the sowing and the reaping of his crops lie too far apart. The yield could not repay such far-reaching ameliorations; and, even if it could, drain-pipes can hardly be used, as the roots would get into them and stop them up. A suitable system of open ditches is the only practicable method applicable in forestry (Burckhardt, *Säen und Pflanzen*, 1893, p. 547).

When land for planting has been fenced, the next step to be taken is to drain all wet portions, and free the whole from superfluous moisture to a depth of 3 to 4 ft.

The Distance between drains depends entirely upon the nature of the soil. On stiff clay or other very retentive soil, they may be required only 11 or 12 yards apart; but in sand or gravel 20 yards may not be too far apart. In Scotland these are about the usual limits.[2]

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[1] It may here be noted that the drainage of land carrying a timber-crop is a very risky operation. It is seldom within the power of the forester to lower the water-level artificially without creating a more or less serious disturbance in the root-system and the general health of the growing crop. Drainage operations should therefore always be completed before the land is planted.

[2] In the North German forests "the distance between the side-drains depends upon circumstances; but, as a rule, this does not exceed 33 ft. (11 yards). A less distance is necessary in *very binding* wet soil, where sideward percolation of water is slow. In some cases not enough of side-drains and feeders are made, or they are formed too large and too far apart to be thoroughly effective. Where the soil is not too light, small trenches often suffice, with perpendicular sides and an upper width of 12 to 16 in.; but then it is well to sink them fairly deep in order to collect the water. In such narrow trenches, which require to be cleared out occasionally, the water runs off better than when smaller quantities of water are distributed over a greater breadth of sole in the drain. They also have the additional advantages of being cheap, and of interfering less with traffic than broader trenches" (Burckhardt, *op. cit.*, p. 547).

The Depth of the drains also depends on the nature of the soil. In heavy clay soil open drains sometimes need to be at least 4 ft. deep, while on light friable land a depth of 3 ft. may often be ample. The more argillaceous or mossy the land, the deeper should the drains be. Drains only 2 to 3 ft. deep are not always able to dry and aerate the subsoil sufficiently for growing timber with profit. For mossy land an allowance should be made for subsidence, as such humose soils generally shrink from a fourth to a third of their bulk after drainage.

The Width of surface-drains likewise varies according to the nature of the land, because it depends on the depth required. A good practical rule *for light land* is to make all drains one-third wider at top than in depth—*e.g.*, a drain 3 ft. deep should have a top-width of 4 ft. to give the sides sufficient slope to support themselves without crumbling down. On stiff retentive land, however, whose sides are firmer and can do with less slope, it is usually sufficient to make the top-width only three-fourths of the depth—*e.g.*, if the drain is 4 ft. deep, the top-width should be 3 ft., while the walls of the small feeder-drains can be cut almost perpendicularly on very stiff land. But these are only rough averages, and of course judgment must be used in applying them, because if drains are made with too little slope, the crumbling down of their sides may cause partial or even total destruction. The base of woodland drains ought to be about 8 in. broad, so as to allow a spade to be passed along them for cleaning them out from time to time, if necessary.

The Cost of Drainage may of course vary greatly; but taking a rough average, woodland drainage may usually be reckoned at about 1d. to 1½d. a running yard according to soil, and 2d. a yard for ditches 36 × 30 × 9 inches.

Stephens' *Book of the Farm* (Macdonald's edition), 1893, Div. V., p. 274, makes the following remarks regarding cost of drainage:—

The cost of cutting drains varies greatly in different localities, fluctuating most in the vicinity of large mining and manufacturing centres, and remaining more stationary in purely agricultural districts. The chief factors which determine the price are the nature of the soil and the depth of the drain. The deeper the drain, the greater is not only the actual cost, but also the cost per cubic yard of soil removed, which may vary from 3d. to 6d. per cubic yard. *Quantity of Earth Removed.*—The accompanying table gives the quantities of soil, or "spoil," according to the depth and average width of the trench:—

TABLE SHOWING NUMBER OF CUBIC YARDS OF EARTH IN EACH ROD, 5½ YARDS IN LENGTH, IN DRAINS OR DITCHES OF VARIOUS DIMENSIONS.

DEPTH.	MEAN WIDTH.											
Inches.	7 in.	8 in.	9 in.	10 in.	11 in.	12 in.	13 in.	14 in.	15 in.	16 in.	17 in.	18 in.
30	0·89	1·02	1·146	1·27	1·40	1·53	1·655	1·78	1·91	2·04	2·164	2·29
33	0·98	1·12	1·26	1·40	1·54	1·68	1·82	1·96	2·10	2·24	2·38	2·52
36	1·07	1·22	1·375	1·53	1·68	1·83	1·986	2·14	2·29	2·244	2·60	2·75
39	1·16	1·324	1·49	1·655	1·82	1·986	2·15	2·32	2·48	2·65	2·81	2·08
42	1·25	1·426	1·604	1·78	1·96	2·14	2·32	2·495	2·674	2·85	3·03	3·21
45	1·34	1·53	1·72	1·91	2·10	2·29	2·48	2·67	2·865	3·055	3·246	3·438
48	1·426	1·63	1·833	2·04	2·24	2·444	2·65	2·85	3·056	3·26	3·46	3·667
51	1·515	1·73	1·95	2·164	2·38	2·60	2·81	3·03	3·25	3·46	3·68	3·896
54	3·604	1·83	2·06	2·29	2·52	2·75	2·98	3·20	3·44	3·666	3·895	4·125
57	1·69	1·935	2·18	2·42	2·66	2·90	3·14	3·38	3·63	3·87	4·11	4·354
60	1·78	2·036	2·29	2·546	2·80	3·056	3·31	3·564	3·82	4·074	4·33	4·584

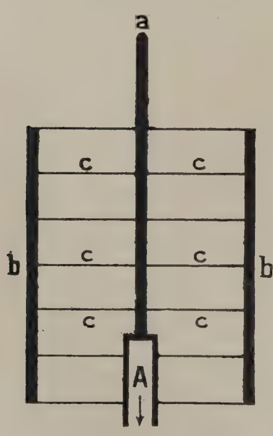
The cost of making trenches and mounds is estimated at about 25 to 30 per cent less than that of making drains, as in the latter case more attention must be paid to the cutting of the slope at a certain angle, according to the nature of the soil (Ney, *Lehre vom Waldbau*, 1885, p. 116).

Laying out of Drains.—On moors and waste lands the drains should be projected so as best to intercept and draw off superfluous water in its line of descent. Unless this be effectually accomplished, the evil it is intended to remedy only becomes aggravated in the lower part of the land. To drain land having a moderate natural descent to one side, all that is necessary is to make the main drains run more or less in the direction indicated by the fall of the ground. The angle at which the feeders should debouch into the side-drains, and the latter into the main drains, depends on the nature of the soil and its gradient. The stiffer the soil and the lower the angle of inclination, the nearer the drains may approach to the angle of 45°, at which the *maximum* effect is obtainable; whilst the lighter the soil and the steeper the slope, the more obtuse should be the upper angle formed between the drains. So far as the individual side-drains are concerned, however, the more nearly horizontal they are, the greater is their effect in draining the land up to the next ditch ; but the greatest total effect is obtained when the whole system is arranged as nearly as practicable at an angle of about 45°. The side-drains and feeders should so be made to debouch into the larger drains that the onward flow of the water may neither receive a check nor scour and injure the larger drain at the point of junction.

The case is altogether different where the ground may appear to be a dead level, because levelling instruments are then required for laying out the proper lines of drainage. Again, where a steep slope with many inequalities is to be drained, the drains should be laid out in the position most likely to intercept the water coming into the hollows from the higher parts ; and to prevent erosion, it is sometimes better to terrace the drains than to keep them at any constant angle.

Where the ground has a natural fall of about 2 or 3 per cent, the drains may be made to run in the direction of the same ; but any higher gradient is too much, and would soon damage the drains during floods. Where the soil is light, sandy, or gravelly, it is best to give only just as slight a fall as will prevent stagnation and carry the water along ; but where the soil is stiff more fall can be given without so much risk of damage.

Fig. 26.



A, *Main drain.*
a, **b**, *Side-drains.*
c, *Feeders* (*horizontal trenches*).

In North Germany it has been found that "from the usual situation of moors [on the North German Plain] one has generally to be content with a very slight gradient. A fall of 1 in 2000 is very favourable, and is even rather too great if much water is to be run off, because too high a gradient causes cracks in the soil. Frequently one must be content to work with a fall of 1 in 6000 or 8000" (Burckhardt, *op. cit.*, p. 562). Under such circumstances, the plan adopted to ensure the speedy setting of the soil (Fig. 26) is that several (usually three) side-ditches, **a b**, 3 ft. broad and 2 ft. deep, are formed parallel to each main drain **A**, at distances of from about 75 to 150 ft. apart, and are connected by horizontal ditches, **c**, 2 ft. broad and 2 ft. deep, formed at distances of 75 ft. apart. By clearing out the ditches from time to time, by deepening them when necessary, and by increasing their number, the work of drainage may be very effectually completed, even with a very slight fall to work upon. In deepening the secondary drains, the operation must of course be begun at the lower end near where it debouches into the main drain **A**.

The main drain having been dug with sloping sides, the side-drains should next be made at 25 to 30 ft. apart, and nearly at right angles to the main drain ; and it is necessary that they should become gradually deeper as they approach the main drain. The lower ends of these side-drains should be kept a few inches above the bottom of the main drain when there is not much fall; for if the smaller drains were to terminate exactly at the base of the main trench, mud would soon accumulate and choke the drain. It is well not to have too many side-drains running into one enormous main drain; it is better to form several main drains. In laying out a drainage scheme it should be recollected that a natural watercourse makes the best outlet for water from main drains. All the drains should be made with regular and equal slope on both sides; and the bottom of each should have a smooth regular run from the upper to the lower end, where it enters the main drain, in such a way that its water will flow on with that passing down the main.

As each drain is opened and completed, the spoil-earth should be spread over the ground between it and the next drain, or at any rate it should be put well back from the edge to prevent it being washed back into the drain.

All side-drains, made between the main drains and the smaller trenches or feeders intended to collect the water, should be of convenient size between the two. All open drains in a wood ought to be examined and cleared at least once every two years; for if not attended to they are apt to become choked by weeds and dead vegetable matter if the ground be level, or by gravel if it be steep and the land be light.[1]

Apart from the spirit-level and the measuring-line for marking off the drains, the only tools required in making open drains on moorland are a turf-spade, a common spade, and a common pick, for taking out stones where they occur; and if the land contains stumps and roots of old trees, a mattock or pick-axe is also needed to sever the roots.

If the natural fall of the ground cannot at once be ascertained by eye, the spirit-level is set up about the centre, and sights are taken all round to fix the lowest point, care being of course taken to deduct the height of the eye from the readings made on the levelling staff. The lowest point on the ground being ascertained, and the size of ditch required there to carry off the water being estimated, a main drain is cut all along the lowest part of the ground and made to empty itself at the lowest point possible. This main drain must be large enough to carry off all the water from the area to be drained; and on nearly level land it must, to provide sufficient fall for the smaller side-drains debouching into it, be deeper than on land having a good slope.

Subsoil Drainage and Aeration.—The draining of wet land is not the only necessary work before planting: a retentive subsoil also needs to be subjected to more or less of preparatory treatment to break the soil up into clods, thus aerating it and making it more easily penetrable by the root-system.

One can easily convince oneself of the advantages of such subsoil-preparation by noting its effect in the growing of Scots Pine, than which no tree is more responsive in this matter. One has only to compare the poor crop of Scots Pine timber obtainable from land with a subsoil of unbroken moorpan with what can be grown on similar land where the binding moorpan has been trenched and broken through. An extreme case is here chosen, but the same result is to be found wherever crops on well-prepared land are compared with those on otherwise similar but unimproved land naturally

[1] Where extensive drainage operations are being undertaken, the use of drainage-ploughs is often advisable as being economical in time and money. Full particulars regarding their capacity, economy, &c., can be obtained from such makers as Messrs Hornsby & Sons, Grantham.

unfavourable for timber-crops. Larch and other deep-rooting trees are also similarly responsive, and even the shallow-rooted Spruce grows far better on improved land than on soil left in its unfavourable natural condition.

It is more particularly in the very early stages of growth that timber-crops derive the greatest benefit from such soil-preparation. Unless the young seedlings or transplants can develop their root-system rapidly and establish themselves well, this affects the whole of their subsequent development, and they never afterwards attain the same vigour as is acquired when they are favourably situated at the very commencement of their life-period. And, of course, the greater the natural tendency of the tree towards forming a strong tap-root, as in all light-demanding genera like Oak, Pine, and Larch, the more beneficial does the soil-preparation prove.

Continental experience shows that—

Low-lying tracts of flat land and other situations tending to wetness, often make cultivation difficult and expensive, not only because the soil is heavier to work, but also because the excess of moisture must be got rid of. To this class belong wet, sour, and marshy soil, sometimes already bearing a thin covering of moorland growth ; damp, cold, binding, loamy sand ; hollows from which the water can only partially escape by evaporation ; and land that is constantly kept moist by stagnating subsoil moisture, especially on old, wet, heather-covered stretches with binding subsoil, which are often marked by the growth of bell-heather, either by itself or along with common heather.

Such tracts must be drained by ditches, while the output from the trenches may be used in preparing the soil. Both objects can be simultaneously attained by forming parallel trenches in connection with the ditches requisite for drainage. In some cases narrow beds or mounds of from 15 to 20 ft. in breadth are formed between trenches of 3 to 4 ft. in width; whilst in other cases the beds are formed up to 30 ft. wide, with trenches of 3 ft. in breadth between, from which the soil is spread over the mounds for immediate sowing and harrowing. . . . Sowings thrive here, as well as plantations; while under certain circumstances even notching succeeds, and Spruce can often be mixed with Pine. But where there is much danger from frost it is better, before planting the Spruce, to wait until the Pine has grown up sufficiently to act as its nurse. (Burckhardt, *Säen und Pflanzen*, 1893, p. 297.)

CHAPTER II.

THE SYLVICULTURAL CHARACTERISTICS OF BRITISH TIMBER-TREES, AND THE DIFFERENT CLASSES OF WOODLAND CROPS: COPPICE, COPSE WITH STANDARDS, AND HIGHWOOD.

THE woodland trees indigenous to any country all exhibit certain marked **general characteristics** and **special peculiarities**, both of which are of importance from a sylvicultural point of view, and may therefore be combined as forming the **Sylvicultural Characteristics of trees.** But as the *general characteristics* arise out of the *special peculiarities*, it is perhaps more convenient to deal with these separately, and to consider the latter first of all, before taking note of the former. It is only by studying such general and special characteristics that one can expect to avoid errors like those, for example, so often hitherto made in planting the Larch.

The **Special Peculiarities** of our chief trees may be conveniently classified as relating to—

1. Climate.
2. Soil and Situation.
3. Light and Shade.
4. Shape of Root-System.
5. Shape of Stem and Crown.
6. Rate of Growth.
7. Reproductive and Regenerative Power.
8. Maturity and Longevity.

1. **Climate.**—The geographical distribution of the forest-trees throughout Europe is partly due to climatic causes and partly to variations in the physical conditions of soil and situation. No kind of tree will thrive except where it can have sufficient summer warmth and a long enough period of vegetation to enable it to carry out in a satisfactory manner the processes of assimilation and of forming ligneous tissue. For the least exacting of our forest-trees a period of three months' vital activity and a mean summer temperature of 54° to 57° Fahr. are requisite, although a very low temperature during winter may also fix their limits, as in arctic Russia and Scandinavia, which are destitute of woodlands. The northern limits of some of our common trees are as follows (Weber, *Die Aufgaben der Forstwirthschaft*, in Lorey's *Handbuch der Forstwissenschaft*, 1903, vol. i. p. 15):—

Species.	Western Europe (Scandinavia).	Eastern Europe (Russia).
Scots Pine	68-70°	64°
Spruce	67-71°	54°
Oak (*Q. pedunc.*)	63°	63°
Beech	60°	50-52°
Silver Fir	49-52° (Germany)	50°

In the same way, the higher the situation above sea-level, the lower the temperature of the air and the soil, and this also causes a more or less irregular distribution of trees throughout vertical zones in mountainous tracts. This climatic influence is increased by the fact (already noted, page 312) that evergreen Conifers, like Scots Pine and Spruce, are limited in their distribution both northwards and vertically upwards, by transpiration being induced on bright sunny days in winter when the frost-bound soil can supply no moisture to replace that evaporated.

The southern limits of our European forest-trees are mainly determined by the quantity and the regularity of the summer rainfall. In the hot dry climate of the Continent it has been found that when rain does not on the average fall once every six to eight days throughout the summer months, the woodland crops are in more or less danger of succumbing to drought, owing to their being unable to obtain the requisite supplies of moisture for the maintenance of transpiration.

So far as regards temperature and rainfall, the climate of Great Britain is exceptionally well suited for all the woodland trees of Central Europe. Scots Pine, Birch, Mountain Ash, and Wych Elm grow better in the colder climate of Scotland than in England; whereas Beech, Pedunculate Oak, English Elm, Sweet-Chestnut, Weymouth and Black Pines, and Silver Fir thrive better in the warmer climate of Central and Southern England than in the northern half of Britain. Scots Pine, Spruce, Larch, Silver Fir, Sessile Oak, and Sycamore are naturally trees of upland tracts and mountain-ranges; Ash, Alder, Pedunculate Oak, Aspen, Elm, Willow, and Poplar thrive best in low-lying localities; Beech, Hornbeam, Maple, and Birch do well both on the plain and on hillsides. Common experience shows that Elm, Sweet-Chestnut, and Pedunculate Oak require most warmth; that Black Pines, Silver Fir, Beech, Weymouth Pine, Sessile Oak, and Scots Pine need more than Birch, Maple, Sycamore, Ash, Alder, and Spruce; and that Larch and Mountain Pine require least.

Although the soil and climate of Britain are generally suitable for growing timber for profit, yet all parts of it are not alike physically endowed in this respect, as might, of course, be expected from the varying nature of the different geological formations, from the range of latitude (from about 50° to 59°), and from the range of elevation.

The great central, eastern, and south-western plains of England, and, next to these, the plains in Yorkshire and Cheshire, offer the most favourable conditions for growing crops of broad-leaved trees. In comparison with these localities, the plateau formed by the north of England and the south of Scotland—from the Mersey and the Tees to the Clyde and the Forth—is, both as to climate and soil, less favoured for sylvicultural and even for arboricultural operations.

Still less suitable is that part of Scotland forming the valleys of the Forth and the Clyde, because they are open, and are swept both by east and west winds for the greater part of the year.

With the exception of the lowlands fringing the Moray Firth, the greater part of the highlands of Scotland is, both as to climate and soil, only suited for the growth of coniferous trees, which here attain finer dimensions and quality than in any other part of the United Kingdom. It may, therefore, be termed the coniferous region of Britain, which produces the finest crops of Larch and Scots Pine.

So far as regards damage from cold, Ash, Sweet-Chestnut, Acacia (*Robinia*), and Beech are most liable to injury by frost; Oak, Silver Fir, Maple, Sycamore, Spruce, Douglas Fir, Willow, Poplar, and Alder are less liable; and Hornbeam, Lime, Elm, Birch, Larch, Sallow, Aspen, and Pines are the most hardy species. The winter cold is not, however, so injurious as late frost occurring in spring when the young leaves and shoots are tender, or as early frost in autumn before the last shoots have become hard enough to endure the cold.

Danger from frost is greater on plains than in hilly tracts; greater on south and south-eastern exposures than on northern and western; greater in valleys, and coombs, and basins, than on ridges and shoulders; greater in localities protected from the wind than in those where currents of air have free play; greater in a dry state of the atmosphere than in a moist; greater on fresh soil than on dry; greater on loose sandy soil than on stiffer loam.

The liability to suffer depends, however, less on the kind of tree than on the stage of growth to which the young shoots have advanced; it is greater in weakly than in healthy and vigorous plants; greater, too, in plants suddenly exposed after having long had the shelter of standards than in those that have been gradually accustomed to the loss of shelter (Nisbet, *British Forest Trees*, 1893, p. 27).

Willow, Poplar, Alder, Maple, Sycamore, and Ash thrive in a fairly humid atmosphere; Silver Fir, Scots Pine, Beech, Aspen, Birch, and Douglas Fir do best with only a moderate degree of humidity; while Oak, Elm, Black Pines, and Larch naturally prefer a rather dry atmosphere. Scots Pine does not thrive in Denmark, though it grows well in our climate, and in Germany it is essentially a tree of the dry sandy tracts; while Spruce, which thrives best in humid hill-ranges (*e.g.*, Harz Mountains in Central Germany), does not grow anything like so well in any part of Britain. Where snowfall is heavy, trees with brittle branches (like Scots Pine) are apt to be damaged; and in localities exposed to violent storms, shallow-rooting trees (like Spruce) are most liable to become windfall.

2. **Soil and Situation.**—What has above been said as to local temperature and humidity with regard to *climate* also applies to *situation*, because in the British islands climatic differences are mainly due to local physical conditions and their influence. The aspect or exposure of any hillside exerts an influence somewhat similar to vertical elevation, because the mean temperature of S.E., S., and S.W. slopes is higher than that of N.E., N., and N.W. aspects, and this naturally affects the growth of woodland crops.

With regard to *soil*, the particular characteristics of each of our forest-trees vary greatly according to the shape of its root-system and the depth to which it goes: even shallow-rooting trees, however, grow best on deep soil, because of the greater facility for obtaining their food-supplies. Most trees require a soil varying from 1 to 3 ft. in depth, and 5 to 6 ft. is about the greatest depth to which even the roots of the Oak penetrate. Some trees form either a strong tap-root or else a deep heart-shaped root-system with side-roots (*e.g.*, Oak, Larch, Elm, Sweet-Chestnut, Pine, Silver Fir, Douglas Fir, Maple, Sycamore, and Ash); others have no well-developed tap-root, but throw out strong side-roots penetrating fairly deep into the soil (*e.g.*, Beech, Hornbeam, Aspen); others again, like the Alder, throw out strong side-roots with strands going down into the soil; while some have only a shallow root-system, like Spruce, Birch, Willow, and Poplar. Spruce, Aspen, Birch, and Mountain Pine can accommodate themselves to the least depth of soil (about 1 ft.), while Oak and Larch require the greatest (3 to 4 ft.) Of the other trees, Scots Pine, Silver Fir, and Douglas Fir need deeper soil than Austrian and Weymouth Pines; while Beech, Hornbeam, and Alder, though not shallow-rooted, can thrive with a less depth than Elm, Maple, Sycamore, and Ash.[1] Depth of soil favours the formation of a long straight bole, whereas a short and gnarled stem indicates at once that the root-system is cramped and unable to develop freely.

As has already been stated, evergreen Conifers make more moderate demands for soil-moisture and for mineral food than broad-leaved trees, while the power of any species of tree to accommodate itself to soil and situation not naturally favourable to its growth usually varies in the inverse ratio of its ordinary requirements as to mineral food and water. Thus the accommodative power is strong in hardy trees like Scots Pine, Aspen, Sallow, and Birch; it is weaker in Oak, Beech, Spruce, Silver Fir, and Weymouth and Black Pines; and it is least of all in Elm, Maple, Sycamore, and Ash.

One cannot generalise broadly and be correct in saying that a clayey, limy, sandy, or loamy soil is, or is not, suited for any particular species of tree (except that Douglas Fir, Sweet-Chestnut, and Maritime Pine will *not* thrive on limy soil), because much depends on other factors (e.g., *humus*).

As regards the chemical composition of the soil, even slightly sour marshy soils are unfavourable to all species of trees except Alder, Birch, and Spruce; while sour soils, liable to dry up at certain seasons, are unsuited to all except Birch, Spruce, Scots and Weymouth Pines. Only these last-named species thrive on pure peat, and not even the Spruce when it is dry. Ash, Maple, Sycamore, and Elm require a moderate quantity of lime in the soil, and Beech, Hornbeam, Oak, as also Larch and Austrian Pine, thrive best on soil that has at least some lime in its composition. The hardwoods — Oak, Ash, Maple, Sycamore, Elm, Chestnut, Beech, and Hornbeam—also appear to require a considerable quantity of potash; while, on the other hand, Spruce, Silver Fir, and especially Scots Pine and Birch, thrive on soil rich neither in lime nor potash (C. E. Ney, *Lehre vom Waldbau*, p. 64).

The total influence of all the factors comprised in *soil* and *situation* show their resultant in the quantity of timber produced per acre, and in its quality for technical purposes. High specific gravity, length and straightness of stem, smooth bark, freedom from knots and branches, and a close compact crown of foliage, all indicate that soil and situation are suitable.

3. **Light and Shade.**—Trees require a certain amount and intensity of sunlight to carry on the process of assimilation of the carbonic acid withdrawn from the atmosphere. Unless such due intensity of light were necessary,

[1] The amount of soil-moisture is of course directly influenced by the depth of the soil, as has already been remarked on p. 311.

there is no reason why the foliage within the crown of a tree should not be as dense as around its periphery. Although excess of light may in some cases paralyse the action of chlorophyll, this never happens to our forest-trees in Britain; and the more light they receive, the better they will grow. Beech leaves, for example, growing in full sunlight are about three times as thick as those growing in heavy shade.

But the various kinds of trees exhibit very marked differences as to the *minimum amount of direct light* they need in order to thrive—or, in other words, as to the *amount of shade* they are capable of enduring. Some kinds are so little tolerant of shade as to be only classifiable as **light-demanding trees**, while others may fairly be called **shade-enduring** or **shade-bearing trees**, and others again occupy an intermediate position. There can never be any hard-and-fast classification of this sort, because even light-demanding trees show themselves more tolerant of shade on fresh soil and in a favourable situation than on dry, average, or inferior land; and, *vice versâ*, shade-enduring trees are less tolerant of shade on poor, dry soil and on hot exposures than on good, deep, fresh land. In woodlands these differences are, however, sufficiently marked to admit of a sort of *rough general classification;* and my observations in various parts of England, Scotland, and Ireland lead me to rank our common woodland trees and coppice-shrubs as follows:[1]—

Light-demanding—

1. Larch and Birch.
2. Scots Pine; Aspen and Sallow; Robinia and Mountain-Ash.
3. Other Poplars and Willows.
4. Austrian and Corsican Pine.
5. Oak, Ash, Elm, and Sweet-Chestnut.

Trees less impatient of shade—

6. Weymouth Pine; Alder, Maple, Sycamore, Lime, and Horse-Chestnut.

Shade-enduring—

7. Spruce, Silver Fir, and Hornbeam.
8. Douglas Fir, Giant Arborvitæ, and Beech.
9. Hazel, Ash, Sweet-Chestnut, Maple, Sycamore, Lime, Mountain-Ash, Holly, and many other shrubs in coppices and underwoods.

Shade-demanding—

10. Beech seedlings for the first two or three years, and Silver Fir seedlings for the first four or five years.

It should be noted, however, that this attempt at classification refers to merely average soil and situation, and to trees after they have thoroughly established themselves and have grown to good pole-size. As very young seedlings, Beech and Silver Fir *require* the shade and shelter of the parent trees for the first two or three years at any rate; but on good fresh soil in Britain, Ash and Sycamore will stand an even greater amount of shade than

[1] This classification differs considerably from that of Heyer (for Central Germany) or Gayer (for Southern Germany). Spruce and Silver Fir endure far less shade here than on the Continent.

these. And in many English copses Hazel, Ash, Sweet-Chestnut, Elm, and even Oak can (owing to our humid climate) endure a far greater amount of shade from the standard trees than they appear able to do in the dry climate of Continental Europe.

Larch is always, and at any age, intolerant of shade, either direct or from the side. Scots Pine can endure a certain amount of side-shade, but none direct from above; Douglas Fir can endure shade, but cannot thrive when subjected to the drip of rain, &c., from above.

The capacity for enduring shade on any given soil or situation is shown by the thickness and persistence of the foliage, and by the length of time overshadowed twigs retain life. Little or nothing is known, however, as to the absolute quantity of light requisite for the assimilative process of any tree.

4. **Shape of Root-System.**—Trees with very branching roots need most growing-space, and are best able to accommodate themselves to rather dry soil (*e.g.*, Willows), while shallow-rooting trees of course do better on thin soil than deep-rooting kinds. Trees with a pronounced tap-root offer greatest resistance to storms (Oak and Larch). Oak, Elm, Ash, Lime, Sycamore, Sweet-Chestnut, Maple, Larch, Silver Fir, Douglas Fir, and Pines have the deepest root-system, while Oak and Sweet-Chestnut retain their prominent tap-root longest. Beech, Hornbeam, and Alder occupy an intermediate position; and Spruce, Birch, Acacia (*Robinia*), Poplar, and Willow are usually shallow-rooted. But of course the root-system is always better developed on good, fresh, porous soil than on stiff, tenacious land.

5. **Shape of Stem and Crown.**—The *woodland* or *artificial* form of a tree is always and necessarily different from the *ornamental* or *natural* form assumed when it has full liberty to ramify both above and below the ground. The more shade-enduring any kind of tree is, the greater must necessarily be such difference, as shown, for example, in the long, straight, clean, branchless boles formed by thick woods of Douglas Fir, Spruce, and Silver Fir, although these trees remain heavily foliaged from top to bottom if allowed to grow in undisturbed possession of sunlight and warmth. The demand for light and the capacity for enduring side-shade is here, of course, *cæteris paribus*, the chief factor in determining the extent to which the *artificial* or *woodland* form of growth can be forced on trees.

The essential characteristic of a *tree* as compared with a *shrub* is that a main stem, trunk, or bole is developed above the root-system, and branches are thrown out to form a crown only at some distance above the soil. Some species of forest-trees tend more to the development of a long straight bole than others, as for example the Conifers generally in comparison with broad-leaved deciduous trees. The individual tendencies of every species are further dependent on several factors influencing them, of which the principal are *the growing-space allowed to each individual, the age of the tree-crop, and the nature and quality of the soil and situation.*

The natural tendency to assume a certain, more or less constant, form has free indulgence only when the individual tree has full enjoyment of light, warmth, and air. Some, by means of the development of the terminal bud of the main axis always taking place with much greater rapidity than the shoots of side branches, assume long straight stems with a more or less conical disposition of foliage, and have a decidedly stronger tendency upwards than sidewards; while in regard to others the terminal shoots of the branches compete with that of the ascending axis, with the result that the stem remains short and stunted, the crown low, and the branch development relatively great. (*British Forest Trees*, 1893, p. 32.)

All our woodland Conifers, except the shrub-like Mountain Pine, have a natural tendency towards forming a good bole or ascending axis, though this tendency is distinctly stronger in Douglas Fir, Larch, Spruce, Silver Fir, and Weymouth Pine than in Scots and Black Pines (Austrian and Corsican). It is also stronger in Poplar, Sessile Oak, Ash, Elm, Sycamore, Maple, Alder, Acacia, and Birch than in Pedunculate Oak, Beech, Willow, Hornbeam, Lime, and Sweet-Chestnut.[1] In all trees the leading-shoot of the central axis develops more vigorously than the side-shoots, and especially when the trees are young (saplings and poles); while in some the side-shoots soon begin to compete with the axial shoot, so that the stem is short and the crown low and wide-spreading. But when each tree is forced to accommodate itself to a limited growing-space, such natural tendency is checked, and competition takes place for individual possession of light and air, so that the main vital energy is transformed into upward growth. The more light-demanding the tree, the greater is this upward impulse to obtain the light and air necessary in the *struggle for existence.*

With regard to the effect of *age* on the form of stem and crown, all kinds of young trees, when grown closely in woods, have a well-defined stem and a narrow spindle-shaped crown till they pass through the pole-stage or most active period of their growth in height; and it is only after this youthful period of development has been completed that their natural tendencies towards ramification become more distinct and irrepressible. Thus Larch, Spruce, Douglas Fir, and Silver Fir usually retain their conical shape longest; the crowns of Pines, Elm, Beech, Maple, Sycamore, Birch, Sessile Oak, Ash, and Alder gradually assume an oval outline; while English Oak and Hornbeam comparatively soon get rounded off into a broad obovate crown. All old trees in course of time get rounded off in the crown, owing to the

[1] Even when grown in the open, Spruces, Douglas Fir and Silver Firs, Larch, and Weymouth Pine retain a distinctly noticeable central axis, which is yet traceable, though less clearly, in Scots, Corsican, and Austrian Pines, Alder, Beech, and Sessile Oak, and to a still less degree also in Ash, Maple, Sycamore, and Elm; while on the other hand the Pedunculate Oak and Hornbeam have a marked tendency to ramification and to the formation of a diffuse crown at no great height above the ground. In woodland crops of normal density the leafy crown of Larch, Pines, Oak, Birch, and Aspen reach only a little way down the stem; those of Spruce, Douglas Fir, Beech, and Hornbeam descend for about one-third of the bole; whilst in Silver Fir they often extend almost half-way down. The effect of the concentration of the crowns of leafy foliage towards the summits of the stems ensures the conservation of the assimilated nourishment for the formation of long, straight, full-wooded stems of the highest possible technical and financial value, in place of this being dissipated over a large branch-system and a stunted stem. That such timber must be more full-wooded (*i.e.*, that the relative proportion between the upper girth or diameter and the lower should show less difference) is easily intelligible, owing to the larger supplies of assimilated nourishment offered under the above circumstances to the upper portion of the bole than to the under part. (*Studies in Forestry*, p. 57.)

upward growth declining sooner than the lateral expansion, but this natural effect of time is less noticeable in Spruce, Douglas Fir, and Larch than in any other of our woodland trees.

Soil and situation of course affect the shape of trees, because of the mutual relation between food-supplies and vegetative energy. Good fresh loam encourages a full crown of foliage and a large girth of stem, but it does not favour length of bole. Deep, fresh, light sandy soil favours length of stem, but the girth is usually small, as there is a sparser branch development and less foliage. Shallow and rocky soil causes branching and stunted growth, because the roots have to spread far in search of food. High elevation and cold windy situations also, of course, cause poor stunted growth.

6. **Rate of Growth.**[1]—The rate of growth of different trees, in *height*, in *girth*, and in *cubic contents*, is one of the most important sylvicultural characteristics, because the possibility of growing mixed crops of any two or more kinds of trees depends essentially on their rate of growth in height and their demand for light or capacity for enduring shade.

Growth in height varies not only with every different kind of tree, but also according to its age, the soil and situation, and the way the woods have been formed and tended. The upward impulse is strongest in Douglas Fir, Spruce, Silver Fir, Larch, and Scots and Weymouth Pines, which can often be made to attain a total height of 100 to 120 ft. in good woodlands in close canopy. Elm, Oak, Ash, Beech, Maple, and Sycamore can, on good deep soil, reach a height of about 100 ft. or more; while Poplar and Birch, Black Pines, Hornbeam, Alder, and Willow seldom attain much over 80 ft.

Douglas Fir (especially the dark Pacific variety), Birch, and Larch (especially Japanese and Kurile Larch), above all others, then Poplar, Alder, Ash, Maple, Sycamore, Elm, Willow, Weymouth, Austrian, Corsican and Scots Pines are the trees that shoot up most rapidly in young plantations;[2] while Oak, Beech, and Hornbeam are comparatively slow-growing at first. Spruce and Silver Fir, especially the latter, are slow in establishing themselves in the soil first of all, but when once well-rooted they are very energetic in upward growth.

It will be noted that, in a general way, the rate of growth in height during the youthful stage of tree-life is more or less proportional to the demand for light and growing-space. Douglas Fir and Larch, and Pines also, on good soil, maintain the advantage gained; but trees like Ash, Maple, Sycamore, Birch, and Aspen soon flag in upward growth, and are caught up and outgrown by Spruce, Silver Fir, Beech, and Oak, when these reach the size of

[1] Statistical details regarding specific rate of growth in height, girth, and cubic contents will be found in vol. ii., Part V., *Management of Woodlands.*

[2] On the Earl of Selborne's estate (Blackmoor, Hants) Larch in eight- to nine-year-old plantations (1895-96) on good soil has been making annual shoots of 3 to 4 ft. high (and sometimes 4¼ ft.), but the Douglas Fir, having thoroughly established itself, is gradually outgrowing the Larch, and has been making somewhat larger shoots (up to 4½ ft.) As Larch is the most light-demanding of all our Conifers, the ultimate result of such a struggle for existence is obvious.

stout poles. How long the upward growth may remain strong and vigorous depends greatly on the soil and situation; but, *cæteris paribus*, among Conifers, it continues longest in Douglas Fir, Larch, Spruce, and Silver Fir, and among the broad-leaved trees longer in Sessile Oak, Elm, and Beech than in other kinds of trees.

Growth in girth is always, in woods growing in close canopy, more or less proportional to the energy of growth in height, because each is the partial expression of individual vigour. In most of our light-demanding trees rapid increase in girth begins early, is usually most vigorous from about twenty to thirty-five years of age, then continues active till about the fiftieth to sixtieth year, when it gradually declines. With Oaks and shade-bearing trees energetic girth-expansion is usually somewhat later in beginning, but is often well maintained till between the seventieth to ninetieth year. When woods are crowded, growth in height is forced on at the expense of growth in girth; and whenever they are kept somewhat open, growth in girth is favoured at the expense of growth in height. When plantations are heavily thinned after growing in close canopy, the trees left standing rapidly thicken in girth as the result of the greater exposure of the crowns of foliage to light and air, and of the larger growing-space allowed for expansion of the crown and of the root-system. Among broad-leaved trees the largest girths are attained by Oak, Elm, Sweet-Chestnut, Lime, Beech, and Black Poplar, and among Conifers by Silver Fir, Douglas Fir, Spruces, and Pines.

Growth in cubic contents, or total increment, is the combined effect attained by the growth in height and growth in girth. As the number of individual stems per acre has to be sooner decreased to provide the necessary growing-space, light-demanding trees culminate in increment and become less energetic sooner than shade-bearing trees, though, of course, here again much depends on the soil and situation. The productive energy of a crop of woodland trees per acre is quite a different thing from the productive energy per individual tree; but, so far as whole crops are concerned, British woodlands may be roughly classified as follows with regard to energy in total increment:—

Conifers—

1. Douglas Fir.
2. Spruce, Silver Fir, and Weymouth Pine.
3. Larch, Austrian, Corsican and Scots Pines.

Broad-leaved Trees—

1. Beech; softwoods (Willow, Poplar, and Alder) on marsh lands.
2. Mixed hardwoods (Oak, Ash, Sycamore, Elm, Maple, and Sweet-Chestnut).
3. Softwoods (Birch, Willow, and Aspen) on dry soil.

7. **Reproductive and Regenerative Power.**—Trees may either regenerate themselves by producing seed or by throwing up suckers from the roots; and if they are cut off near the ground they may reproduce themselves by sending out shoots from the stool. Regeneration from seed is the natural way for all our indigenous trees, and those introduced from other cool climates, to repro-

duce themselves; while the formation of root-suckers is principally confined to English Elm, Lime, and Sweet-Chestnut, introduced from the warmer climate of the South of Europe, and to exotic Poplars and Willows, which cannot in our colder climate be relied on to form seed of anything like average germinable capacity. Among our indigenous trees only Aspen and Willow are able to throw up suckers to any great extent.

The flushing of stool-shoots is in reality far more an effort at recuperation, and an endeavour to replace the stem, than a true regenerative measure. It is entirely due to the vitality still existing in the root-system after the stem has been felled; and until late in life, broad-leaved trees and a few Conifers (though these latter only to a very limited degree) retain the power of trying to maintain the balance between imbibition (through roots) and transpiration and assimilation (through leaves) by throwing out a new flush of shoots and foliage from the adventitious or dormant buds at the neck of the stump. It is thus a recuperative effort to obtain the means of assimilating the food that it continues to absorb from the soil, and death of the roots must ensue if they become charged with water and food which they can neither transpire nor elaborate. This same natural recuperative tendency is utilised in pollarding as well as in coppicing, but in another form and to a more limited degree. In both cases young, soft, thin bark produces a better flush of shoots than old, hard, thick, tough bark; and the recuperative power becomes weakened when once the individual tree has entered fully into the seed-producing stage. Hence only those stems can yield good crops of shoots which are cut back to the stool whilst still in the full energy of development. But in middle-aged and old crops, as can often be noticed very plainly in Beechwoods, dominated trees very often throw out a flush of shoots low down the stem, well below the crown, before they become suppressed. This seems to be a last effort in the struggle for existence, and no doubt in this endeavour a large part of the reserve nutrients stored up in the tree may become utilised, and perhaps wellnigh exhausted. A somewhat similar effort of nature also obtains with regard to premature production of seed (*e.g.*, in Larch especially) in young crops growing on a soil or in a situation not suited to them.

The ability to form seed depends on the amount of starchy and nitrogenous reserves secreted in the tree, and this of course varies according to its age, the soil and situation, and the amount of light and warmth it has recently had the benefit of, because the secretions of nutrient reserves represent *surplus* savings made each year and carefully hoarded for future requirements.

Monœcious trees (*e.g.*, Oak, Beech, Conifers), in which pollination may be interfered with by rain, and the diœcious species (*e.g.*, Willows and Poplars) bear seed on the whole less frequently than trees with hermaphrodite flowers (*e.g.*, Ash, Elms, Maples); while of the latter, those bear seed less frequently which are liable to suffer from frost, or which, as is always the case with Oak and Beech, require that the preceding year shall have been favourable to their growth so as to enable them to form flower-buds. Whereas the seed of Spruce, Silver Fir, and Larch ripen in about six months after flowering, the seed of Pines is not mature until the autumn of the following year, or about eighteen months after flowering (*British Forest Trees*, p. 47).

In good seed-years Ash, Maple, Sycamore, Beech, Oak, Douglas Fir, Spruce, Pine, Birch, Aspen, Alder, and Sallow (Saugh) produce larger quantities of seed than Larch, Silver Fir, Hornbeam, and Elm. But as regards the total quantity of seed produced throughout several years, Birch, Aspen, and Sallow (Saugh) are usually most prolific; then come Pines, Spruces, and Douglas Fir, Ash, Maple, Sycamore, and Alder; then Oak, Larch, and Silver Fir; and last of all Beech, Hornbeam, Elms, and Sweet-Chestnut.

It therefore appears that in general trees with small seeds are more prolific than those with large and heavy fruits; and as these light seeds are usually winged, they easily become wind-borne, so that Birch, Aspen, Ash, Maple, Sycamore, Scots Pine, Spruce, and Douglas Fir have better natural regenerative power than Silver Fir, Oak, or Beech. The regenerative power of Larch is also good, so far as seed-production alone is concerned; but it is so intolerant of shade when young, that it is only when the seed falls on an open spot that it has much chance of being able to grow up there. It is noteworthy, too, that trees of the former class are less exacting and more accommodative as to soil and situation than those of the latter, which capacity, of course, stands in direct relation with the power of forming starchy and nitrogenous reserves of use in forming flowering-buds.

Tree-seeds, however, vary greatly in *germinative capacity*. In Birch and Alder it is below 20 per cent, in Larch it amounts to about 35 per cent, in Ash, Maple, Sycamore, Weymouth Pine, and Silver Fir about 50 per cent, while it is about 60 to 70 per cent in Oak, Beech, Spruce, and Scots, Corsican and Austrian Pines.

The seed of most trees germinates in the spring after it has been shed; but Birch, Elm, Aspen, and Willow seeds sprout soon after they fall in the spring, while seeds of Ash and Hornbeam (also Hawthorn) germinate only in the second spring after their fall.

The most prolific period of seed-production is when trees have completed their main growth in height and have begun to expand their crown, because that is the time when their vital energy is greatest. Good soil, warm situation, and a free growing-space of course favour the production of seed. Birch, Alder, Larch, and Scots Pine begin to bear seed earliest (usually about fifteen to twenty years of age), while Oak and Beech (usually beginning about the sixtieth year) are the latest to enter this regenerative period.

The best quality of seed is produced by middle-aged trees, which is preferable to that gathered from trees just beginning to bear or from very old trees.

In Britain the regenerative power is, on the whole, undoubtedly greatest in Scots Pine and Birch on blanks and open spaces, and in Sycamore and Ash in underwoods.[1]

[1] The following may serve as one of innumerable instances that might be given of the prolificness of Scots Pine:—

Undesirables in the New Forest.—A petition is being signed at Lyndhurst directing the attention of Mr Stafford Howard, Senior Commissioner of Woods and Forests, to the condition of the New Forest heaths and open glades. The Act of 1877, which provided that the whole area outside the enclosure should remain for ever uncut, has in no way been infringed. But nature has taken liberties in the way of planting up the open spaces

The formation of stool-shoots taking place in coppice-growth is, as already remarked, merely an evidence of strong recuperative power. Broad-leaved trees, owing to their larger stores of reserve nutrients, possess this power to a very much greater extent than Conifers, among which (with the exception of the Larch and the three-needled species of Pines) it is almost practically non-existent. This power of quickly replacing sufficient foliage to carry on the work of transpiration and assimilation is strongest during the younger stages of growth, but is always more or less dependent on the soil and the amount of light. Sweet-Chestnut, Oak, and Elm retain such recuperative power longest (to about eighty-five years of age), though Alder, Ash, Hazel, Maple, and Sycamore coppice well, while stools of Beech and Birch lose their reproductive vigour after being coppiced several times.

The formation of suckers seems to be the only means by which certain exotic trees—English Elm, Lime, Chestnut, and most Poplars and Willows—can utilise their surplus starchy reserves, seeing that our climate is not warm enough to admit of their being able to produce seed of fair germinative capacity.

Oak, Beech, Elm, Ash, Maple, Sycamore, Sweet-Chestnut, Hornbeam, Lime, Alder, Goat-Willow (Sallow), and Birch produce more stool-shoots than suckers; while suckers are more frequently produced than stool-shoots from Aspen, Acacia (*Robinia*), Mountain-Ash, non-indigenous Willows and Poplars, and White Alder. But Sweet-Chestnut, English Elm, Lime, and Field Maple at the same time throw out a very fair proportion of root-suckers, which may be severed and transplanted like seedlings. Among coppice-shrubs Hazel produces stool-shoots chiefly, and Blackthorn mostly suckers, while Field Maple throws up both.

8. **Maturity and Longevity.**—Great differences exist as to the age to which the several kinds of trees can continue growing in a healthy condition before showing signs of senile decay. Though many historical trees are known to be much older, the ordinary limits of healthy tree-life may be put at about 400-500 years for Oak, Sweet Chestnut, and Scots Elm, about 200-300 years for English Elm, Silver Fir, and Beech, and about 150-200 years for Ash, Maple, Sycamore, Spruce, Larch, Scots Pine, and Hornbeam, whilst Aspen, Birch, Alder, and Willow seldom attain over 80-100 years. But the above ages are more than twice, or even thrice, the period of rotation that could possibly be profitable in woodlands.

When grown as timber-crops in highwoods the different kinds of trees appear in Britain to reach their greatest market value at about the following age,—but so much always depends on the given conditions as to

with hundreds of thousands of "undesirables" in the shape of self-sown seedling Scottish firs; while in the woods a dense and prickly growth of Holly is blocking up the openings, and hiding one of the most beautiful sights there, the thousands of stems of old forest-trees standing clear and free from underwood. The appeal is that Mr Howard should give directions to check these growths according to the best advice available. The only doubt in our mind (says *Country Life*) is whether the Act, if not amended, will allow him to do so (*Morning Post*, 16th April 1904; see also *Introduction*, chap. i., p. 35).

climate, soil, and situation, that this estimate can only be taken as a rough generalisation :—

Kind of tree.	On good soil. Years.	On inferior soil. Years.
Conifers.		
1. Larch, Scots Pine, and Spruce . .	50-60	40-50
2. Douglas Fir and Silver Fir . . .	60-70	50-60
Broad-leaved trees.		
1. Willow, Birch, Aspen and other Poplars .	40-50	35-40
2. Ash, Elm, Maple, Sycamore . .	50-60	40-50
3. Beech	90-120	80-100
4. Oak	120-150	90-120

With regard to the above-mentioned special characteristics, it should be noted that in many of our British woodlands on fairly good soil, the demand for light made by Oak, Ash, Maple, Sycamore, and other *light-demanding* trees is neither so accentuated nor so clearly recognisable as on the continent of Europe. Our damp climate and the frequent showers that fall throughout the summer months exert a considerable influence in enabling our forest-trees to maintain better canopy than in the dry climate of Central Europe ; but the difference between the good fresh soil of ornamental plantations and game-coverts, and the less fertile soil of the uplands, hills, and mountainous tracts, is probably of far more influence in obliterating important sylvicultural differences and obscuring our recognition of them.

Certain **General Characteristics**, arising out of the above special peculiarities, may be observed when large masses of trees are collected together in the form of woodlands. Each kind of tree then assumes a very definite relation towards itself and towards other trees, for it is either **gregarious** or else **sporadic** in its habit of growth. In the former case such trees become **predominating** throughout whole woodlands, and are capable of forming **pure woods** unmixed with any other kinds of trees ; while in the latter they are always, to a greater or less extent, **subordinate** in number (though not necessarily in commercial value), and thrive best when growing in **mixed woods** along with gregarious trees and scattered throughout such woods and plantations either merely as individual stems or else in small patches or family groups (*e.g.*, the Larch, where indigenous in the Alps).

In the vegetable kingdom, as in the animal, a constant strife is being waged between species, and in the different species between family groups, and in these again between individual plants—a definite *struggle for existence* in perfect accordance with the laws of nature regarding the survival of the fittest. There is, however, this great difference between the animal and the vegetable worlds, that the struggle carried on by forest-trees in the temperate climate of Central and Northern Europe is one which tends to produce a more or less pronounced, though perhaps never absolute, *domination of the principal species* over large areas limited only by the conditions best suited to the growth and development of each individual species (*British Forest Trees*, p. 17).

In consequence of the competition for possession of the soil, which takes place when different species of trees have been intermixed either naturally or artificially, the law of nature regarding *the survival of the fittest* has brought it to pass that, wherever they have long had free scope to make their special characteristics and influence felt, certain species of trees usually predominate numerically over large tracts of country. . . . Our primeval woods probably consisted mainly of Oak and other hardwoods on the better soil, Beech on limy and upland tracts, and Scots Pine on the higher hills and on slopes having only inferior qualities of soil.

If we look at the continent of Europe, we find the Scots Pine the chief tree over the bulk of the sandy stretches comprised within the North German plain, and the Spruce asserting itself throughout Scandinavia and North-western Russia and on the humid mountainous tracts of Central Europe, pre-eminently on the Harz Mountains; a covering of Beech clothes the lower hills of Central and North-western Germany, forming the Deister, Solling, and Thuringian forests; the Silver Fir occupies similar situations in South-western Germany and France, in the Black Forest, and the Jura Mountains; whilst Austria has large tracts wooded chiefly with Black Pine and Larch, and Russia can show its well-defined areas on which Pines, Firs, Hornbeam, Birch, Alder, and Aspen are the dominant species. Speaking generally, the ruling or dominant species of trees throughout the forests of Central Europe, as they now exist, may be said to be Scots Pine, Spruce, Silver Fir, and Beech in the first degree, followed by other Pines, Larch, Oak, Alder, and Birch. These are the species which form the bulk of the individuals in woodland crops; whilst Ash, Elm, Maple, Sycamore, Poplars, Willows, and exotics like Weymouth Pine and Douglas Fir, are only to be found in smaller numbers, or in situations specially suited for their growth. It is, however, rarely that any of these species are now to be found forming **pure forests** in countries where attention has been paid to the most recent developments of scientific sylviculture; for the tendency is now rather towards the formation and maintenance of **mixed woods** as combining important sylvicultural and financial advantages. But, if entirely left to themselves, certain species of forest-trees will ultimately suppress and eliminate most other kinds over tracts of soil better suited to the former than to the latter. Evelyn was to a certain extent aware of this more than two hundred years ago, when he remarked, in one of his letters published in Aubrey's *Surrey*, that "Where goodly Oak grew, and were cut down by my grandfather almost a hundred years since, is now altogether Beech; and where my brother has extirpated the Beech there rises Birch."[1] What might just be expected happens. The shade-bearing and densely-shading species—Beech, Spruce, Silver Fir, and in a less degree Hornbeam and Black Pines—assert themselves over large tracts; whilst other kinds of trees of woodland growth are ousted, and occur merely as subordinate clumps, or groups, or patches, or as individuals scattered here and there over areas and situations unsuited for the predominating species, either on account of the nature of the soil or situation, or for some reason connected therewith (frost, want of moisture, shallowness of soil, &c.) There can, of course, never be rigid lines marking off the domain of the various species; for there must always, in consequence of the various factors connected with the physical conditions of soil and situation, be belts of land where the advantage lies sometimes with one species and sometimes with the other. At the present time on the Continent one has many opportunities of seeing how, in consequence of bad management and of servitudes, under which the peasants were entitled to rob the woodlands of their soil-protecting layer of dead foliage, the domain of the Oak and the Beech is being encroached on by the Pine and the Spruce, which are both more easily satisfied as to soil and situation; whilst these latter again have often to contend with the still more easily satisfied Birch and Willow for the possession of their own areas. It might be argued against what is here stated, that the Scots Pine asserts itself to the exclusion of shade-bearing species on the vast plains south of the Baltic; but this is solely due to the fact that, for the poor sandy soil there, the Pine has proved itself better suited and more accommodating than any other species of tree; and it is in fact merely another example of the survival of the fittest. Even on that sandy plain,

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[1] The significance of this is obvious: "Mr Evelyn remarks that every forest in which Oak and Beech grow promiscuously will, in a course of ages, become entirely Beechen" (Gilpin, *Forest Scenery*, Lauder's edition, 1834, vol. ii. p. 113).

near the fertile lands along the riverine tracts, there is still to be found a stately growth of Oaks, Ash, Elm, Maples, &c., able to hold their own against any attempts at encroachment made by less noble species of woodland trees; whilst the Alder and Willow coppices of those districts are famed. (*Studies in Forestry*, pp. 41-43.)

All *shade-bearing* trees are eminently suited by nature for growing gregariously and forming the **Dominant** or **Ruling Species** over large areas, so that this class includes Beech, Douglas Fir, Spruce, and Silver Fir, while all the other trees are in reality more or less **Subordinate** or **Dependent Species**, unless (1) in quite exceptional cases (see next page), or (2) as the result of artificial operations. Thus Scots Pine is undoubtedly a dominant species over large areas in the Scottish Highlands, but this is due to the accidental fact that no shade-enduring tree is indigenous to the far north of Scotland,—neither Beech nor any other coniferous tree at all,—and so Scots Pine became dominant over large tracts there because it proved itself the best of a poor lot, and happened to possess certain characteristics giving it the advantage over the few other trees (Birch, Willow, Aspen, Alder, Mountain-Ash, &c.) indigenous to that cold, wild, mountainous region. Again, Birch and Alder are also often found forming pure woods, but only on wet land or where nothing else will grow in competition with these very hardy trees, and where shade-enduring trees could not possibly thrive. The Larch has been artificially forced in Britain into the category of a dominant species by being planted in pure woods, and with unfortunate results now. The Weymouth, Austrian, and Corsican Pines share with Scots Pine the ability to form dominant species in circumstances specially favourable to them; but all our broad-leaved trees (except the Beech), all our Pines (except perhaps the Weymouth Pine) and the Larch are naturally **Subordinate** or **Dependent Species**, only suited for growing in admixture with some shade-enduring (and therefore soil-protecting) kind of tree, *if they are intended to be allowed to grow on to full maturity without being underplanted.*

When the **leaf-canopy** or crown of foliage overhead is interrupted to any considerable extent, the soil gets overgrown with grass and weeds, which absorb the moisture and the soluble salts at the surface. And at the same time the soil is exposed to the evaporating and exhausting influence of sun and wind.

For the protection of the soil and the soil-moisture shade-bearing trees form the best crops, because their dense crown of foliage remains in close canopy until the woods reach their maturity. Among broad-leaved trees, Beech therefore ranks first in this respect. Its canopy is close and thick, and the leaves when shed are rich in potash and form excellent strongly hygroscopic humus. Oak-leaves contain too much tannic acid to be good as leaf-mould; while Oak, Elm, Ash, Maple, Sycamore, and the other broad-leaved trees have too thin crowns of foliage to be capable of protecting the soil when they form crops by themselves. Among Conifers, Douglas Fir, Spruce, and Silver Fir are best able to protect the soil by their thick canopy and to improve it by their dead foliage; while below the Weymouth and the Black Pines mosses grow and act like humus in absorbing and retaining moisture. Larch especially, and also Scots Pine, are too thinly foliaged to protect the soil properly, although a good layer of moss usually shields the soil from the effects of sun and wind until the canopy begins to get broken, when the moss gives place to a rank growth of grass, whortleberry, or heather, and the soil soon deteriorates. On marshy land planted with Alder, Birch, Willow, and Poplar, the evaporation due to sun and wind often reduces the excessive quantity of moisture, and is therefore beneficial rather than injurious.

To obtain the best returns in timber from the soil, the woods must be of **normal density**—*i.e.*, must have a full or **close canopy**—neither too crowded on the one hand, nor too sparsely stocked on the other—for the given kind of crop. Crowding is disadvantageous. If each tree has not sufficient growing-space, it cannot have the light, air, and warmth needed for healthy growth, and therefore soon sickens and falls a prey to insects or fungous diseases. The constant struggle for existence at the same time becomes unduly prolonged, and this dissipates the energy which, by judicious thinning, can be better utilised for the benefit of the mature crop. But if there be too small a number of trees per acre for the given kind of tree and class of soil (*i.e.*, an unnecessary large growing-space be allowed), then vegetative energy will be dissipated in branch-formation, instead of being utilised to form a long straight stem. And, at the same time, the broken leaf-canopy is insufficient to protect the soil, which will soon get overrun with weeds.

Different kinds of trees are not alike able to retain close **leaf-canopy** or **normal density** after they have passed through the early stages of development, for they make different demands for light.

To estimate these differences it is only necessary to compare the crown of a Beech or a Silver Fir with that of a Birch or a Larch, although in these cases extremes are purposely chosen in the two classes of broad-leaved trees and conifers. This physical fact, that all trees of forest growth are not alike endowed with the capacity of shading the soil and protecting it against the exhausting influences of sun, wind, and rank growth, is a matter of very great moment from the sylvicultural point of view. Although all our forest-trees may be grown in pure woods, if worked with a low rotation, owing to timber-crops being naturally dense during the thicket period (that is, till the crop begins to clear itself naturally of dead branches), and during the pole-forest stage of growth (which means till the leading stems have attained a girth of about 2 ft. measured at breast-height), yet after that, when once they have entered into the tree-forest or high-forest stage of development, their natural individual differences with regard to demands for light—*i.e.*, growing-space—and with respect to density of foliage in the interior of the leafy crown, begin to make themselves unmistakably apparent. Thus, whilst thickly foliaged kinds of trees, like Beech, Silver Fir, and Spruce, can be grown in pure forests until they attain their full technical and mercantile maturity, without the productive capacity of the soil being endangered, it would be contrary to one of the leading principles of Sylviculture—viz., the conservation of the productive capacity of the soil—to cultivate pure high-forests of **light-demanding genera** like Oak, Ash, Maple, Pine, or Larch, except under special circumstances where the productive capacity of the soil is not endangered by insufficient cover, as, for example, on some classes of marshy land where the evaporation caused by insolation and by the free play of wind is directly beneficial, or on low-lying tracts with fresh soil, whose depth and porosity might

Fig. 27.

An English Larch-wood (*Tring Park, Herts*, 1900).

The soil is densely covered with a thick, tangled growth of blackberries and other weeds.

perhaps be injuriously affected by any accumulation of humus. It is solely with regard to the soil-protecting capabilities of the different forest-trees that the classification of **Dominant** or **Ruling** and **Subordinate** or **Dependent Species** is based; for it may be briefly stated that the productive capacity of woodland soil is only safeguarded to the necessary extent when the timber-crop consists either of thickly-foliaged species growing in close canopy and providing the soil with a good layer of leaf-mould, or else of Conifers having evergreen foliage under which a covering of mosses performs the functions of the humus or mould elsewhere. The species of trees naturally fitted to be grown in pure forests under the first of these conditions are pre-eminently Beech, Common and Menzies Spruce, Douglas and Silver Firs, and in a less degree Hornbeam, Lime, and Chestnut; whilst those falling under the second condition comprise the several varieties of the Pine genus, so long as they are not worked with too long a period of rotation —*i.e.*, so long as their fall is not delayed too long after the time when they sink so far below the normal density of canopy that the growth of mosses gives place to weeds and berries, and the soil begins to deteriorate through insufficient protection against insolation and exhausting winds. Unfortunately the broad-leaved trees best qualified by nature for the formation of pure forests are not in Britain of sufficient technical and commercial value to lead to their cultivation on any large scale; but among them the Beech . . . is of great sylvicultural importance as the ruling species or matrix, . . . along with which the more valuable classes of timber-trees, Oak, Ash, Maple, Sycamore, Birch, &c., may be most profitably grown on localities where the soil would be liable to deterioration if the woods consisted of these thinly-foliaged and light-demanding species only. (*British Forest Trees*, pp. 35-37.)

The number of trees per acre which will form **normal density** or **close canopy** must, of course, vary according to the branch formation and the shade-enduring power of each tree. In Germany, on soil of the best quality for each kind of tree, it has been found that at the age of 120 years there are 37 per cent more Beech, 24½ per cent more Silver Fir, and 60 per cent more Spruce trees than Scots Pine per acre. On good soil there is always, at every age of the crops, a very much smaller number of trees per acre than on poor soil, because the struggle for individual existence is sooner decided on good than on inferior soil. On the best class of Pine soil, Scots Pine-woods consist, at eighty years of age, of only about one-third as many trees as are generally found on the poorest class of soil. Although the number of trees per acre is larger on poor than on good soil, yet the normal density is maintained longer on the better classes of land. But the actual extent to which a timber crop may overshadow the ground varies greatly, because German investigations have shown that in a normally dense Spruce-wood the soil is overshadowed to more than double the extent that obtains in a normally dense Scots Pine wood.

The largest quantity of timber per acre is produced in woods of normal density. Other things being equal as to soil and situation, the increment is largest in trees fully exposed to light, air, and warmth, because their root-systems are larger and can draw more food from the soil, while the greater extent of foliage can carry out the assimilative and tissue-forming processes more actively and thoroughly. The total yield per acre from woods in close canopy is not only greater than that from more open crops, but the quality of the timber is also better, because the larger the individual growing-space, the more is the tendency to branching growth. To grow long straight timber, it is therefore necessary to keep a plantation in as close canopy as is reasonable until it has passed through the pole-forest stage of most active growth in height (which again varies for each kind of tree). After crops complete their chief growth in height in canopy of normal density, a free thinning soon enables the stems to increase rapidly in girth, so that even with the diminished number of trees per acre, a greater increment and a more valuable yield is obtainable than if the crop had been allowed to remain growing in normal canopy.

As is very evident from the history of Forestry in Britain from the fourteenth to the eighteenth century (see *Introduction*, pp. 15-28), the national form of Arboriculture was to select certain kinds of trees (principally Oak for shipbuilding, Ash, Elm, &c.—*all of them light-demanding trees*) and to allow them to grow up into timber, while the rest of the wood (formed of Hazel, Ash, Holly, Beech, Chestnut, &c., partly shade-enduring, partly impatient of shade) was felled (*coppiced*) once every seven or eight to twenty-four years or more. Such woods were in the old statutes termed **Coppices** or **Copses**, and they form the true national British system of Forestry still more or less characteristic of most of the woodlands throughout the milder parts of the United Kingdom, though the management of such woodlands has become to a great extent a lost art owing to economic changes during the last hundred years. In course of time the term **Copse** became synonymous with the German *Mittelwald*, or the French *Taillis sous futaie*, and the method of treatment has thus been described by Gilpin (*Forest Scenery*, edit. 1834, vol. i. p. 301) :—

> The copse is a species of scenery composed commonly of forest-trees intermixed with brushwood, which latter is periodically cut down in twelve, thirteen, or fourteen years.

It is convenient to have a different term for woods of low rotation where no timber-trees are retained, but all the crop is felled ; and this form of treatment is more specifically known as **Coppice**, while **Copse** is also called **Stored Coppice** or **Coppice with Standards.**

In the Beech-woods on the limestone hills of Southern England and in the Pine forests of Northern Scotland, and also wherever extensive plantations of the trees have been made with a view to the production of timber, the form of cultivation is known as **Highwood** or **High Timber**, the only form suitable for the growing of Conifers.

There are thus in Sylviculture three definite **Forms of Woodland Crops**, viz. :—

(1) **Coppice**, for growing poles, rods, brushwood, and tanning-bark.

(2) **Copse, Stored Coppice** or **Coppice with Standards**, for the simultaneous production of timber and of bark (**Standards** or **Overwood**) and of smaller material (**Underwood** or **Coppice**) in one and the same wood.

(3) **Highwood**, for the production of timber.

Strictly speaking, Copse is not a combination of *Highwood* and *Coppice*, because this latter forms a special method called *partial clearance with under-planting.* Copse is an independent form of treatment, in which, from about the age of ten or twenty years upwards, the standard timber-trees are allowed (as was particularly the case for special shipbuilding reasons long ago) a large growing-space, so as to ramify far more than can ever be reasonable in well-managed highwoods. It was practised in England for centuries before the highwood method of growing timber received much special attention.

1. **Coppices** can be formed of any kind of broad-leaved tree, but none of the Conifers possesses sufficient reproductive power (as in Larch and the three-needled Pines) to be grown in this way. So far as reproductive vigour is concerned, Sweet-Chestnut, Oak, Lime, Maple, Sycamore, Hornbeam, Ash, Mountain-Ash, Alder, and shrubs like Hazel, Holly, Buckthorn (*Rhamnus*), and Dogwood (*Cornus*), are superior to Beech, Birch, Sallow, and Aspen, although softwoods are, on the whole, naturally best suited for becoming dominant on moist land, whereas hardwoods are usually by far the most profitable on dry well-drained soil. But any decision as to the best coppice crop to grow on any given land, and the best period of rotation (seven, ten, twelve, or twenty years, or more), depends, like the broader question as to coppice of any sort being preferable to highwood or copse, mainly on what market is available, and whether the owner desires profit, utility, game-cover, or ornament. So long as Oak-bark for tanning still sold well, pure coppices of Oak on warm southern aspects were often very profitable portions of estates. This was one of the most extensive forms of Forestry throughout Ireland, where many thousands of acres of old Oak-coppices, planted on poor land unsuited for agriculture, and now unable to grow much beyond pole-size, form the profitless remnants of a once flourishing industry long since ruined by free trade and cheap chemical products.

Except for the production of Oak-bark, coppice-crops were seldom grown throughout the colder parts of Great Britain or in Ireland, although they used to be largely cultivated in the central and southern counties of England, where fuel was scarce, and where hop-poles were always in good demand. But now the new system of growing hops on posts-and-wires has changed this. Even during the course of the last thirty years or so, the value of coppices has in most cases shrunk to only from one-third to one-half of what it used to be.[1] Nowadays it is not a form of woodland that is ever likely to be again cultivated on any extensive scale on poor shallow land, because even there Conifer crops have, on the whole, a better chance of being profitable. Moist land, where softwoods grow really well, can usually be drained to serve

[1] "From the author's experience previous to the recent fall in the value of bark, 20s. per acre per annum was about the average return derivable from Oak-coppice, whilst Birch and Alder yielded on the average about 18s., and Ash about 30s. per acre. Coppice of a general mixed character he never found profitable, as it seldom realised more than 12s. per acre per annum. The above valuations are taken from coppice cut down at periods varying from fifteen to twenty-five years" (Brown, *The Forester*, 5th edit., 1882).

Nothing like these prices are now obtainable, and there seems no prospect of any rise in value (see *Introduction*, p. 50).

a higher purpose. Coppices of Alder-Buckthorn or Black Alder (*Rhamnus frangula*), Dogwood (*Cornus*), Alder, Hazel, Birch, Mountain-Ash, Willow, and Wild Cherry are no longer so profitable as they formerly were for making charcoal for gunpowder; and even Ash, Oak, Hazel, Chestnut, Sycamore, &c., from the underwoods in copses, now scarcely find any profitable market in rural districts. Perhaps softwood coppices, formed extensively on moist land, might prove profitable for wood-pulp, if once the price of wood-pulp imports rises high enough; and this would come within the definition of *Sylva cædua*, so important for entailed estates (see *Introduction*, chap. ii., p. 59).

At the present time the most valuable and profitable coppices are **Osier-holts**, of which there are between 7000 and 8000 acres in Great Britain, producing about 20,000 tons of rods or withes annually. The fen districts of Lincoln and Cambridge, and similar alluvial deposits, are suitable for this industry, which might be very largely increased if an effort were made to win back the trade in fruit-baskets, &c., from the hands of Continental Osier-growers.[1] The following are the chief kinds of Osiers grown as coppice (*British Forest Trees*, p. 327):—

Of the smaller Willows cultivated in Osier-beds, the True Osier (*S. viminalis*) is the most important, being characterised by the toughness and flexibility of its thin withes, which grow in thick clusters; the Laurel Osier (*S. triandra*) yields a plentiful crop of long flexible twigs; the Purple Osier (*S. purpurea*), so called from the colour of its anthers during the time of flowering, produces very thin but exceedingly tough withes, principally used for basket-making. So far as the various species can be determined by their leaves alone, the following short descriptions may be of use:—

S. viminalis—Leaves very long, with white close-lying hairs having a silky gloss. Stipules small, temporary or fugacious, shorter than the petiole, or altogether wanting.

S. triandra—Leaves quite smooth, finely serrate.

S. purpurea—Leaves often opposite, smooth, bluish-green, lanceolate, finely serrate towards the apex and becoming somewhat broader; without stipules.

Periodical inundations stimulate the growth of Osiers. Floods in winter do no harm, even if lasting for weeks, but any lengthened submersion during summer is injurious to the crop. Mounds must be thrown up on soil that is too low-lying and wet, whilst stagnant water must be brought into circulation by digging trenches or ditches. Most Osier-beds show a mixture of species, the ruling kind depending to a great extent on the nature of the soil and situation, and, as the Willows have a very great tendency to cross, the number of species is constantly on the increase; thus *pentandra* and *fragilis* yield *S. cuspidata*, *purpurea* and *viminalis* yield *S. rubra*, &c. In the formation of new Willow plantations the species should be segregated as much as possible in the various beds, according as the concrete factors of soil and situation promise the best returns, for the different Osiers have distinct preferences in this matter, as well as in other sylvicultural respects. From this point of view Esslinger has classified them into the following main groups:—

1. *True Osier group* (*S. viminalis*, &c.), demanding a light moist soil, and best capable of standing wetness of soil: yield a very good outturn of useful material for

[1] Leaflet No. 36, on *The Cultivation of Osiers*, can be obtained gratis from the Board of Agriculture by those interested in this matter.

basket-making and wicker-work, but much liable to attacks from insects. These are the principal species for cultivation on sandy soil.

2. *Laurel-Osier group* (*S. triandra, S. amygdalina, S. hippophaëfolia*, &c.), demanding a light, fresh, or moist soil, and yielding withes of first-rate quality for technical purposes. These species suffer comparatively little from insect enemies.

3. *Purple Osiers* (*S. purpurea, S. rubra*, &c.), content with a dry soil, and yielding numerous, but thin, withes, suited for all technical purposes; not much attacked by insects or rats.

4. *Caspic or Pruinose Osiers* (*S. acutifolia = S. pruinosa = S. caspica, S. daphnoides*, &c.), whose young shoots are covered with a bluish soft bloom, thriving on dry soil, and yielding clean but not numerous shoots of 10 ft. in length, only suitable for coarser technical purposes.

According to the Board of Agriculture pamphlet, the total cost of preparing and planting Osier-holts varies from £14 to £23 an acre. The crop matures in four or five years, and then yields about £15 an acre, taking 150 bunches of green rods as the average crop (although heavy crops yield 250 bunches, worth £25 per acre). If cleaned at a cost of about 8d. a bunch (or £5 per acre), the 150 bunches will give 100 bunches of white rods, worth about £35 per acre.

A holt planted in a suitable site, well planted, cleaned, and cared for, filled up and replanted when necessary, has always paid its way; and where the circumstances allow of peeling the rods, a very good result has been obtained.

The attention of Osier-growers may be drawn to the fact that Osier-bark contains from 8 to 12 per cent of tannin, and is used on the Continent for the preparation of *Russia leather* and the *Danish kid* of glovemakers.

Osier-growing is, however, from the amount of attention it requires, far more of the nature of Horticulture than of Forestry. Coppices like Oak-bark hags, Ash- and Alder-groves, and Osier-holts should be kept pure, and care should be taken to prevent the intrusion of softwood seedlings springing up from light wind-borne seed, because any such admixture only causes trouble and loss in sorting the crop harvested. But in all other coppices a mixture of different kinds is of advantage, both because it enables variations in the quality and freshness of the soil to be better utilised, and also because, in such cases, one can more easily supply local demands for different kinds of material, such as hop-poles, pea-sticks, bavins, hurdle- and crate-woods, fuel-faggots, &c.

The *rotation of the fall* in coppices must of course depend on the local market, the satisfaction of whose requirements often offers a difficult problem for the forester to solve. It sometimes happens, for instance, that there is a fair demand for Hazel rods of about seven or eight years old, while there is little or no sale for Ash until it is from twelve to fourteen years old, and but little local demand for any other kinds of small wood, whether hard or soft. To fix the rotation at seven to ten years is best for the Hazel, but the Ash is then unprofitable; to make the fall only every twelve to fourteen years gives one the best market for the Ash, but the best Hazel market is then missed; while if the rotation be fixed at ten years, the forester falls between two stools and finds great difficulty in disposing of the coppice crop at all. These are practical difficulties which can only be solved by common-sense and a full knowledge of all the local conditions. But the longer the rotation of the fall, the less frequently is the soil laid bare, and the less is consequently the danger of the surface-soil deteriorating in productivity. Osier-holts are generally coppiced annually, but otherwise the rotation usually varies from seven to twelve years for mixed coppice, from twelve to sixteen for Oak-bark, and from twenty to twenty-five or thirty years for Alder, the form of coppice most closely resembling a highwood in appearance.

The Pollarding or *Lopping* of Willows and Poplars growing near the edges of streams in meadows is more of an agricultural than a forestal measure.

2. **Copse, Stored Coppice,** or **Coppice with Standards.**—For this form of crop the ideal would be an *overwood*, consisting of one or more kinds of *light-demanding* trees, and an *underwood* of shade-enduring kinds. One can obtain the latter much more easily in France and Germany than in Britain, because on the Continent Beech and Hornbeam, the two most heat-producing of all our woods, both find a ready sale everywhere as fuel, whereas this is nowhere the case in any part of Britain. As was commanded in the *Statute of Woods* (1543; see Part I., p. 17), "12 standils or storers of Oak" were to be left per acre, or, failing Oak, that number was to be made up with "Elm, Ash, Asp, or Beech,"—all of which, except the last, are light-demanding trees, beneath whose shade the coppice could have a much fairer chance of growing fairly well than under the denser shade of more heavily foliaged trees. Oak, Ash, and Elm had then a far greater value than now, and many of the old trees in our copse-woods date from the time when this statute was still in full operation. On good, fresh, heavy loam Oak and Ash are still the best and most valuable standards, while, as in simple coppice, Hazel, Ash, Chestnut, and Sycamore usually form the most profitable part of the underwood. As Britain does not consume such wood as fuel, there is no market for Beech and Hornbeam coppice as in France and Germany.

It seems doubtful if ever there was really much of systematic method in the storing and utilisation of standards in the old English copses; at any rate, none of the writers on Arboriculture, from the seventeenth to the nineteenth centuries, give any account of method save merely in the selection of young saplings or of sturdy stool-shoots or suckers as stores. As in coppices, the rotation of the fall is usually based on local market conditions. It ranges in different parts from seven to twenty-five years. Where the disposal of the underwood permits of this, the best rotation is twenty or twenty-five years, because the soil is then better protected than when more frequently laid bare. Improvements now being made in the management of copse-woods in some parts of Southern England, are therefore based mainly on the more regular method evolved in France and Germany.

Note on Continental Copse (*Mittelwald: Taillis sous Futaie*).—Each time **underwood** is coppiced, young **stores** are selected, of seedling growth if possible, and are successively retained to form the **standards** or **overwood**, the *oldest* class of which is harvested along with the coppice at each rotation. The number of stores left at each fall (*i.e.*, the total extent to which the standards may be allowed to overshadow the area) depends on the amount of shade the underwood will endure, and this of course depends on the freshness and productivity of the soil, and on the kinds of trees forming the coppice-crop. It is only on the very best classes of woodland soil, and when the underwood consists entirely of species that bear shade well (like Beech and Hornbeam, or in a less degree Maple, Sycamore, and Chestnut), that the standards are allowed to stand in such number as nearly to overshadow the whole area. On poor land, or when the underwood contains a considerable proportion of light-demanding species (like Oak, Ash, Elm, Willow, Poplar, Birch), the standards just before the fall should not overshadow more than one-fourth of the area. But between these wide limits the conduct of operations is left to the forester.

It will thus be seen that good returns from both standards and underwood can only be expected from land above the average in quality, and that the standards should be lightly-foliaged, while the underwood should be of whatever shade-bearing trees can be disposed of locally to the best advantage. The three main sylvicultural factors regulating the treatment of copse-wood crops are—(1) freshness and productivity of the soil, (2) lightness of crown in the standards, (3) shade-bearing capacity, and consequent density of crop, in the underwood.

As the crown of foliage and therewith the amount of shade cast over the soil gradually increase with the age of the standards, it is found necessary to diminish their number at each fall. Thus, for example, if the fall take place every twenty years—*i.e.*, if one-twentieth of the whole area be coppiced annually—and if the oldest trees are then one hundred years of age, the following will be the ages of the different classes forming the overwood :—

Immediately before the fall.	Class of wood.	Immediately after the fall.
20 years of age	Underwood	0 years of age
40 "	young Stores	20 "
60 "	double Stores	40 "
80 "	young Trees	60 "
100 "	old Trees	80 "

If it be assumed that, on a rough average (which is probably not far wrong), the area overshadowed by each individual tree of these different classes becomes doubled in the twenty years (though this varies, of course, with different kinds of trees), then equal areas will always be overshadowed by—

1 old Tree = 2 young Trees = 4 double Stores = 8 young Stores.

Hence, if at the next fall of timber the same disposition of standards is desired as has hitherto obtained, this can conveniently be regulated by allowing the younger classes, from stores or standels up to standard trees, to remain on the ground in the given proportion. In this case the wood and timber harvested at each fall would remove—(1) *all* the underwood (except the seedlings left as Stores), (2) *all* the old Trees, (3) *as many* young Trees, (4) *twice as many* double Stores, and (5) *four times as many* of the young Stores left standing at the last fall.

And in like manner, if more or less overwood be thought desirable, with due consideration to the productivity of the soil and the respective nature of the standards and of the underwood, then lighter or heavier clearances among the various classes of standards may easily be calculated, as seems best for the given soil, situation, kinds of trees, and local market. Gayer's critique of copse-wood is as follows, *so far as Germany is concerned:*—

This system undoubtedly offers attractions to private owners whose woodlands are too small in area to be treated as highwoods yielding a regular fall every year. But great regularity of treatment is hardly practicable over extensive areas, because changes in the quality and depth of soil necessitate, in all properly managed woods, variations as to the kinds of underwood and the kind and number of the standards. . . . Thus, for example, if standards of forty or sixty years can be sold better than older trees, then the overwood may be confined solely to the production of such trees along with the underwood ; or if there be any specially favourable market for stout Larch of that age, then good transplants may be planted here and there at each fall, because with this environment Larch finds specially favourable conditions for very rapid and exceptionally healthy growth.

In many parts of Germany the principle of this method has been carried so far as to have coppice of two ages, which differs from the system of reserving standards merely in so far as the stores are usually only of coppice-growth, instead of being raised from seed, as is the proper way in copse.

For ship-crooks of Oak, or forked growth of Ash for furniture, the copse has special advantages. But although it protects the soil better than pure coppice, it is distinctly less protective than a highwood crop. And there can be no doubt that the general requirements of the future timber-market will be better met by growing long, straight, clean stems in the close canopy of highwoods than under conditions in which ramification and coronal development are greatly stimulated by the undisputed possession of a large individual growing-space.

Of the total quantity of wood produced, a much higher percentage falls into the less valuable class of branches and brushwood in copse than in highwood. While this seldom amounts to more than 20 per cent in highwood, it often rises to 40 or 50 per cent of the total outturn from standards over coppice. (Gayer, *Waldbau*, 1889, p. 159.)

On the Earl of Selborne's estate (Blackmoor, Hants) there are old copses, dating probably from time immemorial, at an elevation of 300 to 500 ft. In 1900 a scheme of management was adopted, based upon a twenty years' rotation, with a view to (1) a more regular and methodical clearance of mature standard trees, and to selecting sound young Oak or Ash poles to take their place as timber, and (2) the improvement and thickening of the underwood. The standards forming the overwood are mostly of Oak, varying from 2 to 7 ft. in girth and often with enormously branching crowns, and of Ash of somewhat inferior growth, all scattered irregularly over the areas; while the bulk of the coppice, often with large blank spaces, consists mostly of Hazel, with Oak, Ash, Birch, Willow, Aspen, and in some falls a little Chestnut, Beech, and Sycamore. The manner in which the clearance and the replacement of the mature standard trees are being effected is indicated in the following extract from the scheme of management:—

Owing to the great irregularity of the present crops, in which old standards are plentiful but young stores scarce, the formation of different classes of standards varying regularly according to age can only be achieved in course of time. With this end in view, the storing of overwood should be regulated as follows:—

Storing of Oak Standards in Copse, the Rotation of the Fall being once every Twenty Years.

Age-class of standards.	Number of standards selected to remain.	Age.	Average individual growing-space at commencement of each rotation.	Total area overshadowed by the standards—	
				Just after each fall.	Just before each fall.
		Years.	sq. ft.	sq. ft.	sq. ft.
Young Stores .	40	20	25	1,000	7,000
Double Stores .	20	40	175	3,500	9,000
Young Trees .	10	60	450	4,500	7,000
Old Trees .	5	80	700	3,500	5,000
Total . .	75	...	...	12,500	28,000
Proportion of overshadowing by standards . . .				about $\frac{2}{7}$ of area	nearly $\frac{2}{3}$ of area

Note.—For *Ash* the number of standards may be 50 per cent in excess of above for Oak, and mixtures of Oak and Ash as overwood should be calculated on these bases.

Considering the good quality of the soil, the above estimated amount of overshadowing towards the close of each period of rotation does not seem such as will prove excessively prejudicial to the coppice underwood; but the overwood is most to be considered as likely to yield the main portion of the revenue. In addition to the clearance of the coppice, each fall will every twenty years be carried out as follows:—

Removed during each fall.			Standards left after each fall.			Remarks.
Class.	Age.	No.	Class.	Age.	No.	At each fall there will therefore be removed, along with the coppice, *all* the old trees, *an equal number* of young trees, *twice as many* double stores, and *four times as many* young stores.
	Years.			Years.		
Coppice . .	20	all	Coppice-stools	...	...	
Young Stores	40	20	Young Stores	20	40	
Double Stores	60	10	Double Stores	40	20	
Young Trees	80	5	Young Trees	60	10	The *average* growing-space of the standards will be $\frac{43560}{75}=580$ sq. ft., and the *average* distance from stem to stem will be $=\sqrt{580}=24$ ft.
Old Trees .	100	5	Old Trees .	80	5	
Total . .	...	40	Total . .	...	75	

The young stems selected as stores should be of seedling growth if available, and in any case they should be of good straight development with a well-shaped compact crown of foliage. At each fall the inferior stems of each class in the overwood should be cleared away and utilised, leaving the best to attain the larger and more remunerative dimensions. As the future prospects point to advantage in the storing of Ash, this tree should, on the whole, receive the preference when selecting the standards, not only on account of a larger number being retainable per acre, but also because, thus treated, it may be expected to attain its full maturity within 60 to 80 years, whereas Oak might often require 100 to 120 years, and the latter, involving five classes of standards, seems inadvisable in dealing with the small areas now under treatment. As a general rule, it will perhaps be found advisable to remove all the Ash standards at the age of 60 or 80 years, and only to allow Oak to grow up as old trees to 100 years of age.

Where some of the older standards may have to be removed before the fall of the coppice, they should be lopped of all large branches and of the crown in order to reduce the amount of damage done to the underwood when felling.

As the overwood is at present very irregular, the falls are being gone over twice during the next twenty years—*i.e.*, in sub-periods of ten years, but solely with a view to try and get a better proportion and gradation of standards. Before that time it will be decided whether it will be preferable to continue regular copse treatment with a rotation of twenty years or transform the woods into high timber. In either case the present management will benefit the future condition of the woods.

The filling of blank spaces and the improvement of the underwood is being accomplished by the plashing or layering of stool-shoots of Ash, Chestnut, Hazel, and other hardwoods.

Of course, the above mathematical regularity is merely an ideal to be aimed at, but it can never be either attained or maintained in actual practice.

With regard to the above estimate of the probable overshadowing in the Earl of Selborne's copses, *on good soil* and in a favourable part of England, it may be noted that Galmiche (*Étude sur les Réserves des Taillis sous Futaie*, 1893) estimates the area covered by standards in French copses to be *on the average* as follows (Boppe et Jolyet, *Les Fôrets*, 1901, p. 243):—

Area of standards.	Square metres.	=Square feet.
At 25 years of age	insignificant	...
" 50 "	22	=242
" 75 "	58	=638
" 100 "	89	=979

Allowing for the five years' difference in the rotation of the fall, this gives very much the same result as above estimated for overshadowing.

3. **Highwood** or **High Timber** is the term applied to woods (usually raised from seed, either by natural regeneration or artificially by sowing or planting) which are not cleared as a crop until they have either reached their full maturity or are at any rate of sufficient age and dimensions to yield a crop chiefly consisting of marketable timber (*i.e.*, measuring at least 3 in. in diameter, over bark, at the top end).

This is the only form in which crops of coniferous trees can be grown, and it is also, on the whole, by far the best way of growing crops of broad-leaved trees with the main object of producing long clean stems of timber.

Sylviculturally, two main classes of *Highwoods* may be distinguished,—(1) those that are *clear-felled* in whole or in part, and are either regenerated naturally from seed blown over from adjoining crops (or from portions of the crop still left standing) to the windward, or else are renewed artificially by sowing or planting; and (2) those that are *regenerated naturally under parent trees*, the regeneration taking place either *more or less casually throughout the whole wood* ("selection fellings"), or else *gradually in small family groups*, formed successively throughout a block of woods over a period of years, or *more or less simultaneously over a whole block of woodland* as good seed-years offer suitable opportunity. These two main classes and their specific treatment can be more appropriately considered when dealing with the *Renewal of Woodlands* (see chap. vi.)

Highwoods may either be *pure woods*, consisting of only one kind of tree, or they may be *mixed woods*, where two or more kinds of trees are grown together. The soil is best protected when the woods, pure or mixed, consist entirely or mainly of shade-enduring trees (Beech, Douglas Fir, Spruce, and Silver Fir); but under special conditions—sometimes of soil (as in wet or boggy land), sometimes of situation (as at high elevations), and sometimes of the available market for timber—the best prospect of profit is often held out by pure or mixed woods of light-demanding trees, such as most of the hardwoods and all the softwoods, together with the most valuable of our conifers, Larch and Pines. In mixed highwoods the ultimate *mature crop* is usually one consisting of the most valuable kind of tree (usually a light-demanding species—*e.g.*, Oak in mixed woods of Oak, Beech, and other hardwoods, or Larch in mixed woods of Larch, Pine, Spruce, and Silver Fir), this being left as long as convenient to thicken in girth, while the other kinds (usually wholly or chiefly shade-enduring trees) are being regenerated naturally.

Pure Highwoods.—*All kinds of shade-enduring trees can be grown in pure highwoods*, because by their dense overshadowing and the large fall of dead leaves they preserve, and usually greatly increase, the productivity of the soil. This is also to a great extent the case with the evergreen conifers, the Pines, under which a thick spongy growth of moss springs up when once the trees begin to thin themselves, though this mossy protection disappears as the crop ages and the leafy-canopy becomes more and more broken. But much less protection is afforded to the soil in the case of the more thinly foliaged and less shade-enduring deciduous trees, which should therefore, *theoretically*, only be grown in pure woods—

1. *When they are either to be felled at a comparatively early age or are later on to be underplanted.* Even the light-demanding trees maintain a closer leaf-canopy and protect the soil better up to about 30 or 40 years (and longer with Oak) than is possible for them after their most energetic period of upward growth is completed and the impulse for lateral expansion (light and warmth) becomes more necessitous (*e.g.*, Larch and Pines up to about 25 to 30 years; Ash, Elm, and Sycamore up to about 30 to 35; and Oak to about 35 to 50).
2. *When the productivity of the soil is not likely to be much impaired by imperfect cover* (*e.g.*, mixed Oak, Ash, and Elm on deep, good, fresh alluvial land; Alder, Birch, Willow, and Poplar on low moist tracts, where sun and wind help to evaporate the excess of moisture).
3. *Where either the soil, the situation, or the local market point to one species as being far more suitable than any other* (*e.g.*, Banks' or Scots Pine on poor, very dry, sandy soil; Austrian Pine on very deteriorated lime; Ash-groves and Alder-beds on wet land).

So far, *theoretically;* but *practically* it sometimes happens that there is apparently only one sort of wood saleable at a fair profit, and then, if he plant at all, the landowner often prefers to plant that (*e.g.*, pure crops of Larch, notwithstanding the considerable risk there always is of canker).

Mixed Highwoods.—Apart from tendencies here and there for certain trees to become dominant over extensive tracts (see p. 333), on the whole, nature's way of producing the most valuable kinds of timber is to grow them in mixed woods. Continental experience shows that mixed woods are in many ways more profitable than pure woods. They offer the following advantages:[1]—

1. *The crop is thicker*, thus giving a larger yield and affording better protection to the soil.
2. *They produce timber of larger size and better quality* (*e.g.*, Larch when grown with hardwood; Oak, Ash, &c., grown with Beech).
3. *They are less exposed to windfall and snowbreak, or to attacks of noxious insects and fungous diseases.*
4. *It is easier to modify or transform the crop* either in following or in anticipating changes in the timber market.

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[1] Those specially interested in the views of German foresters on the subject of **Pure** or **Mixed Woods**, will find in *Studies in Forestry*, 1893, pp. 115-157, a much more detailed summary than is here convenient.

5. *Natural regeneration is, on the whole, easier than in pure crops.*

6. *They are more picturesque*, from the varied tints of foliage they offer in spring and autumn, and also in winter when evergreen Conifers are mixed with deciduous trees.

The main *disadvantage* chargeable against them is that they involve more trouble, which is perfectly true. But this can be reduced to its minimum if the mixture takes place (following nature's method) in family groups according to special suitability of soil or situation, and not in any stencil-like regularity such as alternate rows, or a quarter of one kind and three-quarters of another, distributed equally over all the area, &c.

General Rules for the Formation of Mixed Woods[1] have thus been framed by Gayer (*Der Waldbau*, 1889, p. 216), in accordance with the laws of nature and the principles of sylviculture :—

1. *The soil and situation must be favourable to the development of all the kinds of trees intended to be grown in admixture.*—It would be erroneous to suppose that mixed crops are advisable only on the better classes of soil, although of course the quality of the latter is an important factor in determining the choice of species to be admixed. In fact, it is on some of the poorer kinds of land that the greatest general advantages of mixed woods make themselves most apparent, particularly when the soil is of a sandy nature.

2. *The admixture of species must not be such as ultimately to endanger the productivity of the soil.*—This is practically a repetition of the first principle laid down with regard to the formation of pure forests by shade-enduring trees, and amounts to the statement that the capital value of the woodland soil (*i.e.*, its capacity for yielding interest or returns in timber under proper treatment) must not be risked or diminished by injudicious management.

3. *Throughout the whole period of rotation each species must have sufficient growing-space, and light, air, and warmth for its requirements.*—This condition is not confined to the development of the crown, but applies equally to the extension of the root-system ; and it becomes of all the more importance, the nearer the individual kinds of trees approach their physical maturity.

Heyer (*Waldbau*, 1891, p. 45) has also formulated rules for the formation of mixed woods, based on the general considerations that the possibility of forming mixed crops of various kinds of trees is dependent—

(*a*) *On their individual capacity for protecting or improving the productivity of the soil ;*

(*b*) *On their relative demands with regard to light ; and*

(*c*) *On their relative rate of growth in height.*

His rules are as follows :—

1. *The dominant or ruling species must be capable of improving the soil.*—That is to say, the matrix should consist of trees like Beech, Douglas Fir, Spruces, Silver Firs, and Pines.

2. *Shade-bearing trees may be grown in mixed woods when their rate of growth is about equal, or when the slower-growing kinds are protected against the quicker-growing.*—The protective measure in the latter case consists of giving some start at first to the slower-growing species, of allowing it to form the great majority of the crop, or of favouring it at the time of natural regeneration, and later on by

[1] *British Forest Trees*, pp. 143-146.

lopping, topping, or even thinning out the other kinds of trees threatening to suppress it.

3. *Shade-bearing (thickly-foliaged) trees can be intermixed with light-demanding (thinly-foliaged) trees, when the latter are of more rapid growth in height, or when they are afforded some advantage as to age or height.*—If, however, the shade-bearing kinds are to be expected to develop vigorously, instead of being suppressed during the youthful period of growth, they must form the dominant or ruling species numerically.

4. *Light-demanding trees should not be permanently associated together as timber-crops.*—When the slower-growing species is at the same time relatively the more capable of bearing shade (*e.g.*, Pines and Larch), exception to this rule can be made—

(*a*) On very good soil not exposed to deterioration under the light canopy of the thinly-foliaged species. Under such conditions a mixed growth of Alder and Ash, Oak and Elm, Oak and Maples, &c., is not at all injudicious.

(*b*) On very poor (sandy) soil, principally given up to Conifers, where of broad-leaved trees the Birch alone is content to grow.

Except on soil and situation where the Scots Pine shows itself more shade-enduring than is usually the case, a mixture of this species and Larch is not at all advisable, although very often made in Britain.

5. *The subordinate species should be introduced individually and not in patches or groups.*[1]—Here again, however, exceptions may be made—

(*a*) When the quality of the soil is variable, so that patches here and there are specially suited for any one particular class of tree (*e.g.*, Spruce on shallow stony soil; Ash and Alder on damp wet spots; Pines on dry patches).

(*b*) When a light-demanding species is to be grown along with a shade-bearing species of quicker growth (*e.g.*, Oaks grown in admixture with Beech on soil specially favourable to the latter).

(*c*) When standards (*e.g.*, of Oak) are retained for a second period of rotation. Here some protection is afforded to the soil until the young seedling crop forms canopy, and at the same time the formation of shoots from dormant buds along the stem, leading too often to "*stag-headedness*," is prevented.

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[1] This is not a good rule, unless it should happen, as will very rarely be the case, that the more light-demanding tree is always growing just very slightly in advance of the less light-demanding. It is therefore usually best to imitate nature in forming groups of different trees on spots specially suited to them. But the groups must never be so large as to risk the deterioration of the soil to any great extent in the case of light-demanding trees with sparse crown and thin foliage. It is not possible to define the best size of such groups; a mere academic assertion that they should not exceed 25 or 40 yards in diameter, or about one-quarter to one-third of an acre, for example, is of no practical use whatever. The given circumstances must be known before any common-sense opinion can be formed.

The natural tendency to regeneration in patches or family groups is, of course, most pronounced in trees having heavy seeds (Oak, Beech, Chestnut, Silver Firs, and certain Pines). But all light and winged seeds, like Elm, Ash, Birch, Willow, Scots Pine, Spruce, and Larch, are more likely to spring up sporadically at considerable distances from the parent trees; and the same applies to the regeneration of trees whose fruits form part of the food of birds.

Soil is seldom homogeneous throughout woodland tracts, but usually varies in depth, moisture, and other physical properties. Here there is a patch of good soil; there, close by, it is not as good; in some spots it is moist, in others dry; and the forester notes these variations and tries to utilise them. This can only be done by judicious admixture of the different species, here in big groups, there in small patches, and again by introducing a few individual plants only. Such a practice is merely imitating nature: it is done successfully on the Continent, and there is no reason why it cannot also be done in Britain.

In forming mixed woods, there can be no intention that all the species shall grow up together till the crop is finally harvested. If plantations are made at 4 ft. by 4 ft., with 2722 plants per acre, it would be a physical impossibility for anything but a small proportion of these, say from 100 to 200, to reach maturity. And Birch or Maples, for example, could not hold out the same period of rotation as Pines, Spruce, Firs, Oak, and Beech, for they attain maturity at a much earlier date. The express intention is always to utilise certain kinds of trees when they are marketable, and when their removal will benefit the species to remain on the ground; hence it usually happens that in mixed crops only one individual species remains to be finally harvested as the mature crop.

Mixed Crops of Shade-bearing Trees are never likely to be of much importance in Britain, as neither Spruce nor Silver Fir grow so well here as on the Continent.

1. **Spruce and Silver Fir.**—Where Spruce is dominant, Silver Fir diminishes the danger of windfall and of insect attacks; but where Silver Fir dominates, any admixture of Spruce has the opposite effect. As Spruce is of more rapid growth, the Silver Fir should be introduced in larger number. If two of Silver Fir be planted to one of Spruce, the mature crop will consist of about equal numbers of each.

2. **Beech and Spruce.**—Beech is of quicker growth at first, but soon gets caught up, and Spruce then usually remains predominant. Even if Spruce be only scattered singly throughout the crop, some lopping of the branches may be required. Where stony outcrops occur in Beech-woods, it is best to form pure clumps of Spruce.

3. **Beech and Silver Fir.**—At first the Beech interferes with the Silver Fir, but is afterwards overtaken and suppressed.

4. **Douglas Fir with Spruce, Silver Fir, or Beech** is likely to prove a good mixture, as it grows more quickly, but will probably not interfere much with their development.

Mixed Crops of Shade-bearing and Light-demanding Trees.

1. **Spruce dominant.**—All light-demanding trees grow quicker than Spruce, and damage its leading-shoots when it is catching them up. It overtakes most of them, and must be kept in check unless the other trees are thinned out.

(1) *Spruce with subordinate Oak, Ash, Maple, Sycamore, or Elm.*—The hardwoods are usually caught up by Spruce between fifteen and twenty-five years of age, unless they predominate in number, in which case the Spruce remains partially or entirely suppressed. It is not a mixture that has anything to recommend it in Britain.

(2) *Spruce with Birch, Aspen, and Willow.*—Not at all to be recommended. They all shoot ahead, and then (especially Birch) whip the leading-shoots of the Spruce. Although good nurses in damp frosty places, their strong reproductive power makes it difficult to get rid of them when no longer wanted.

(3) *Spruce and Scots Pine.*—At first the Pine protects the Spruce against frost and heat; but if it exceed one-seventh to one-fifth of the crop, it interferes for a long time with the growth of the Spruce, and later on its spreading crown scours the Spruce leaders. On dry sandy soil the Pine is of quicker growth throughout, but on fresh soil the Spruce catches up the other after about thirty to thirty-five years, and then remains predominant. A mixture of these trees is, as a rule, only advisable on medium soil; but as Pine fetches a much better price than Spruce in Britain, the thriving of the Pine is the main object.

(4) *Spruce with Larch.*—This mixture is similar to that of Spruce and Pine, except that the Larch remains permanently predominant. On poor or shallow soil, however, the Larch is overtaken, and can then be cut out, as it has no further chance against the Spruce.

2. **Douglas Fir and Larch** form an excellent mixture in groups or patches, but not in alternate lines. The Larch is at first the more rapid in growth, but Douglas Fir either catches it up and suppresses it entirely, or else the Larch continues its advantage, and then the side-twigs scour and damage the tender leaders of the Douglas Fir (see p. 251).

3. **Silver Fir as a ruling species** much resembles Spruce, but is not so apt to suppress the subordinate species when once it catches them up in growth.

4. **Weymouth, Austrian, and Corsican Pines** can bear a fair amount of shade, and improve the soil with their thick foliage; so that they are suitable for forming a matrix for Larch.

5. **Beech dominant.**—Continental sylviculturists have an enthusiasm about the Beech as the ruling species that can hardly be intelligible to British foresters.

Thus Gayer says of it (*Waldbau*, 1889, p. 448):—

> There are many localities in which Beech will continue to be a valuable wood from a financial point of view [*i.e.*, for fuel in Germany]. But where such may not be the case, it will still retain its unsurpassable sylvicultural value; for *without the Beech there can no more be properly tended forests of broad-leaved genera*, as along with it would have to be given up many other valuable timber-trees, whose production is only possible with the aid of Beech.

Ney (*Lehre vom Waldbau*, 1885, p. 93) is equally enthusiastic:—

> The Beech, which in pure crops belongs to the more valuable species of trees only on account of its protective influence on the productivity of the soil, is of extraordinary value in mixed crops owing to its capacity for casting a dense shade over the ground and for improving the soil by its strong fall of leaves. When an admixture of Beech is judiciously formed, all species of timber-trees show a much greater energy of growth than in pure crops. It safeguards the productivity of the soil better than any other species of tree, and therefore well deserves the name of "*the Mother of the Forest*" which has been given to it.

(1) *Beech with Oak.*—Oak grows quicker than Beech except on shallow (especially limy) soil. But the start it gets is seldom sufficient to protect it against the Beech. It is usually better to form pure crops of Oak first of all, and then to thin heavily and underplant them with Beech at about sixty to eighty years of age, when the main growth in height has been obtained. Or strong Oak transplants can be set in blank patches in Beech seedling-growth, and favoured during all operations of thinning.

On good soil the Oak may be planted so as to far outnumber the Beech; but on merely average soil each Oak should be surrounded with Beech, when there will seldom be more than eight to ten mature Oaks per acre at 100 to 120 years of age, though on the best classes of soil there may perhaps be thirty to forty per acre.

(2) *Beech with Ash, Maple, Sycamore, and Elm.*—All these trees resemble the Oak in their attitude towards the Beech. All are of quicker growth at first, and they usually retain this advantage on deep fresh soil, otherwise they are caught up by the Beech during the pole-forest stage of growth. On fresh soil they sow themselves so freely as to interfere with the natural regeneration of the Beech; so it is best to cut them out before preparing the soil for the Beech-mast, and merely to plant them here and there singly or in small patches throughout the new seedling crop. But in most cases they will have had to be thinned out long before the time comes for regenerating the Beech (90-120 years).

(3) *Beech with Birch, Aspen, and Willow.*—Such mixed woods sometimes occur self-sown to such an extent that the softwoods become extremely difficult to get rid of. Scattered singly here and there, they protect the Beech against frost, and often yield fair returns when cut as early thinnings. But when in large number they interfere with the Beech, and must be cut out as soon as possible. On account of their strong reproduction and rapid growth as coppice-shoots and stoles, it is better to lop them and leave snags of 2 or 3 ft. standing than to cut them flush with the ground. With the early removal of such softwoods, a good opportunity is offered for introducing sturdy transplants of more valuable trees. But if not weeded out very early, they can only be gradually removed during subsequent thinnings, because the Beech-poles get drawn up so fast that without the partial support of the softwoods they would become top-heavy.

(4) *Beech with Larch and Scots Pine.*—Larch and Pine are throughout all stages of more rapid growth than Beech, and protect it from extremes of heat and cold. These conifers here attain their largest size and best quality. Under the light cover of Pine, natural regeneration of Beech is easier and better than under the heavier shade of the parent trees.

As Scots Pine begins to spread its crown early, it should be given no advantage in height to begin with. It can easily be introduced by sowing or planting here and there throughout the young seedling Beech crop.

Mixed Crops of Light-demanding Trees.—Where low-lying tracts with good moist soil are still under timber, mixed woods of Oak with Ash and Elm, or with Alder and Birch,—of Alder with Ash, Birch, and Aspen,—and of Pines with Aspen and Alder,—and the like, are often to be seen growing well and yielding good returns.

Larch and Scots Pine are undoubtedly in Britain the light-demanding trees most frequently found dominant, and at the same time they are the two conifers most frequently found mixed. Unless the soil is good and deep, the Larch soon gets caught up and pressed by the Pine; while on really good soil an admixture of Douglas Fir is much more profitable than Pine. On the poor tracts forming true Pine soil, the trees best suitable for admixture with it are other Pines, Austrian and Corsican; but on moist sandy soil a sprinkling of Sweet-Chestnut often acts very beneficially, and may afterwards be coppiced.

At what age the **Fall of Timber** should take place in highwoods, depends mainly on the facilities for sale and the prices obtainable. If the crops be properly tended, and thinnings have at all times been restricted to the removal of unhealthy and unnecessary trees only, then the different kinds of trees will, *in pure woods*, mature at about the ages stated in the table on page 333. But *in mixed woods* the subordinate trees continue growing well for somewhat longer on soil specially suitable to them, while on other classes of soil they have to be thinned out at an earlier age. There can be no hard-and-fast rule about the matter. The effect of unnecessarily heavy thinnings is to exhaust the energy of the crop and make its increment sink prematurely, as has elsewhere been pointed out (see *Introduction*, p. 54, and chap. v. below).

When mixed highwoods are being regenerated, in cases where no change of crop into some more profitable kind is desired, it is essential to proceed by means of natural regeneration in the case of Beech and Silver Fir, whose young seedlings demand protection against both scorching and frost. Once the dominant crop is fairly renewed, the subordinate species can easily be interplanted to the desired extent.

The **Yield in Timber and smaller Wood** of course varies greatly for the different forms of woodlands and the different classes of soil. Unfortunately, no British data are yet available; but Continental data concerning the intermediate thinnings and the final yield or mature crop will be found in vol. ii., Part V., *Management of Woodlands* (Appendix III.)

Conversion of Coppice and Copse into Highwood is often desirable. Good saplings from seed or suckers, and the best-grown stool-shoots, should be selected at about 18 or 20 ft. apart and left standing as permanent stores, merely the inferior ones being thinned out during subsequent falls of the coppice. As the standards increase in their crowns, the underwood will diminish; but this cannot be avoided. The opportunity may at the same time be taken to introduce stout transplants of Oak, Ash, &c., on suitable land, as seedlings are always better than stool-shoots or suckers. Another method, often by far the most profitable, which was largely carried out in Ireland about fifty or fifty-five years ago, is to plant Larch about 20 ft. apart. They find just the environment most favourable to them, and grow up into large and valuable stems. They may need some little protective care during the first two or three years, but after that they grow out of the reach of the coppice-shoots.

Critique of Coppice, Copse, and Highwood Crops.—Continental experience has shown that (subject to exceptions, of course) **Highwoods** are, on the whole, the best, and usually the most profitable, timber-crop, then **Copse** or **Coppice with Standards**, and that **Coppice** is the least economical, because least conservative of the productivity of the soil. But Osier-holts, or Oak-bark coppice, wherever young bark is still well paid, or Alder-coppice for clog-wood, charcoal, &c., may all prove, under favourable conditions, much more profitable than copse or most kinds of highwood. And certain classes of copse may easily pay better than certain classes of highwoods, because they lock up far less capital, and for other obvious reasons.

When once coppice or copse has been formed, each rotation of ten or twelve to twenty or twenty-five years involves only a comparatively slight outlay for filling blanks, whereas the capital sunk in highwood crops keeps growing at compound interest and increases rapidly, unless there be a good return from thinnings.

On entailed estates the laws relating to timber (highwoods) and *Sylva cædua* (coppice and copse) (see Part I., p. 59) are points often of much more importance to landowners than the prospect of future gain from timber-crops that may perhaps only mature about thirty or forty years hence.

Theoretically, **coppice-woods,** in which the crop is formed entirely of small shoots containing relatively larger quantities of mineral substances than are to be found in mature wood, must tend to exhaust the easily available supplies of lime, potash, and phosphoric acid sooner than any crops grown as **highwoods.** And this theoretical deduction coincides exactly with the results of practical experience; for it is well known that Oak-coppice for tanning-bark, or Osier-holts for withes, should only be made on good land, and that if inferior soil be cleared of Oak-coppice every twelve to sixteen years, it runs great risk of deteriorating.

Coppice-woods in general, and more especially those in which the crops consist of Ash, Elm, Lime, Oak, or Willow, the kinds of trees making the highest demands on the soil for nutrients, tend more towards the exhaustion of woodland soil than **Copse** or **Coppice with Standards**, in which only the underwood is cleared away periodically at comparatively short intervals of twenty to twenty-five years; while this composite form of crop is in its turn less conservative of the productivity than **Highwood** crops.

The frequent deterioration of soil under coppice does not occur on account of these kinds of trees making high demands *per se* for food-supplies, although for young poles, shoots from stools, and stoles of sucker-growth, considerably higher demands are continuously being made than would be the case if these were to be allowed to develop into young trees having a larger proportion of ripe wood to the foliage and bark in which the mineral ashes are chiefly deposited; but it is mainly ascribable to the fact of the soil being laid bare to the exhausting influence of sun and wind every twelve to sixteen years on the hags being cut over for the harvesting of the crops of poles, bark, or small material.

The treatment of timber-crops in **highwood** is, as long sylvicultural experience has clearly shown, the most conservative manner of utilising the soil; while **copse** or **coppice with standards** stands about midway between the two other systems, as being less exhausting than coppice, though more exacting than highwood.

Highwoods can never lead to exhaustion or deterioration of the soil, so long as this remains protected by a sufficient leaf-canopy, and is not robbed by wind, or otherwise, of the natural manure obtainable through the decomposition of the dead foliage. On the contrary, and more especially in the case of trees like Scots Pine and Spruce, which make lower demands for potash and lime than other species, it is almost always the case that the nutrient salts contained in an available form within the soil at the end of the period of rotation—*i.e.*, on the fall of the mature timber—are considerably in excess of the quantity that was present at the time of such crop being formed, provided always that the fertility or productive capacity of the soil has been duly safeguarded by the maintenance of a good unbroken canopy of foliage throughout all the life-periods of the crop. For this reason woods formed of trees like Pines, Spruces, and Firs recommend themselves for the recuperation of the productivity of soil that has been allowed to deteriorate by being kept long under lightly-foliaged kinds of trees like Oak, Ash, Elm, or Larch; because the broken canopy formed by these light-demanding species is unable, without the aid of undergrowth, to protect the surface-soil from the exhausting influences of sun and wind, and from having the accumulated supplies of humus consumed unprofitably by a more or less rank and unremunerative growth of weeds.

So far, therefore, as conservation of the productivity of the soil is concerned, highwoods in general, and those formed of thickly-foliaged species in particular, or copses of standard trees having a good protective soil-covering of underwood, are certainly the forms of woodland crops most thoroughly satisfying **the first fundamental principle of Sylviculture**—viz., *that the natural productivity of the soil must be carefully conserved, in order that it may satisfy continuously and uninterruptedly all rational demands made on the land with regard to the production of timber or of other woodland crops.* Both the quantitative yield and the qualitative outturn in timber, or in other woodland produce, are dependent on the manner in which this fundamental principle is kept in view. If, on merely average or inferior land, such kinds of crops be formed, or methods of treatment be adopted, as imperil the productivity of the soil, then any extra returns that are promised in the immediate future must be dearly purchased at the cost of the inevitable ultimate deterioration of the land for timber-production. *It would, in fact, be merely discounting the future productivity of the land, and decreasing its capital value* (*Studies in Forestry*, pp. 88 and 260, 261).

CHAPTER III.

SOWING, NURSERY WORK, AND PLANTING.

When woodlands are formed artificially for the first time, they must either be **sown** or **planted**. As a matter of fact, the choice between sowing and planting has practically been settled in this country by the general adoption of planting, owing to the luxuriant growth of weeds in our damp climate, although **sowing** or **dibbling** of acorns had long been practised in the English copse-woods before **planting** was introduced in the seventeenth century.

The advantages of the artificial production of woodlands, as compared with natural regeneration, consist mainly in being independent of seed-years, and in the freer hand left with regard to the general nature of the crop and the introduction of other trees in forming mixed woods. And when simple and comparatively inexpensive methods are adopted, sowing and planting are not necessarily more expensive than natural regeneration where large blanks require to be filled artificially. The main points in question may thus be summarised (*Studies in Forestry*, pp. 172-176):—

Where woodland crops are to be formed for the first time, a choice exists only between sowing and planting, in connection with which—leaving out of sight the special requirements of the various genera and individual species of forest-trees—certain general considerations require to be weighed.

With regard to the soil, experience has shown that, on places unfavourable to the early development of young crops, planting is preferable to sowing, owing to the greater sensitiveness and need of protection of young seedlings during the first stages of their existence. And better results are usually obtainable from planting than from sowing, both on very damp, wet, cold, or stiff soil with a tendency to being lifted by frost, and on very loose soil apt to dry up easily, or such as may have become deteriorated superficially through insolation and exposure to exhausting winds, or which is liable to inundation, &c. Where, owing to rank herbage of grass and weeds, young growth has to struggle for its very existence, sowing is the exception, and planting the rule, more especially when the genera of trees forming the young crop are of slow initial development. Unfavourable situation with regard to climate, by retarding the growth during the first few years, also weights the balance in favour of planting, especially in raw damp localities exposed to frost. Where planting is to take place on tracts that have been drained, but which are still damp enough to show a strong growth of rank weeds, sturdy transplants of hardy species, little sensitive to frost (Pines, Birch, Aspen, Alder), should be planted out during autumn with balls of earth attached to their roots, or even tumped on mounds if the soil is actually moist. For, as Hartig well remarks (*Diseases of Trees*, p. 15): "When trees or shrubs are planted and their natural process of development has been so much interfered with that the new shoots are not thoroughly developed by the time frost sets in (*i.e.*, that the process of forming woody tissue has not been properly completed), such plants possess an abnormal disposition towards damage from frost. They may hold out in mild winters; but, if severe cold occurs, the plants may be killed outright." On all soil that is merely fresh and of a light mild consistency—the happy mean between loose and stiff, neither apt to become too heated nor too rapidly cooled, and having no immoderate tendency towards rank growth of weeds—sowing is principally adopted, as also on rocky, stony outcrops where there is hardly sufficient soil for the proper carrying out of planting operations.

On the Continent sowing was formerly most generally practised, and it was not until the introduction, on an extensive scale, of the method of total clearance with artificial reproduction that the present preference for planting became general abroad. In Scotland, the total destruction of the Pine-woods, originally clothing vast extents of mountain-sides now barren, naturally led to the artificial formation of forests wherever the proprietors desired to grow timber. And, in the vast majority of cases, the conditions of soil and situation—raw northern climate, rank growth of heather, heath, and other weeds, and deterioration of the surface-soil by long exposure to the effects of sun and wind—naturally pointed to planting as the best, and often the only, means of attaining the object in view. Good nursery seedlings and sturdy transplants must have less difficulty in establishing themselves than tender seedlings germinating on the area and having to overcome various disadvantages (drought, heat, cold, weeds) during the first two or three years of their existence.

Where sowing can take place under the shelter of standards, or in the lee of crops nearly mature, it is much more likely to be satisfactory than in the open. But, under nearly all circumstances, there is usually a good deal of work and outlay required for the filling up of blanks; hence the final cost of the formation of such young crops is not always less than if planting had been carried out over the whole area at the very outset.

Until nursery seedlings or transplants have established themselves in their new abode, there is always a disturbance and a diminution of the activity of the root-system; and this is accentuated by the trimming often requisite even in young plants, and always necessary in older transplants. In this respect sowing certainly has the indisputable advantage over planting of permitting a more natural and uninterrupted development of the root-system, and of effecting a better accommodation of the latter to the nutrient characteristics of the soil. The disturbances occasioned in transplants vary according to the species of tree, the method of planting, and the nature of the soil. Shallow-rooting species with good reproductive capacity establish themselves much more rapidly than deep-rooting species; while, on fertile soil, the efforts made towards accommodating themselves to the new conditions are more quickly responded to than on soil of merely average or indifferent quality.

By the use of transplants, too, many of the dangers from insect enemies during the first years of growth are avoided, although experience in many different localities has shown that sowings suffer on the whole less from *Curculionidæ* than where plantations are formed with small seedlings.

Comparisons between crops formed by sowing and by planting during the last half-century have shown that in very many cases plantations yield the better results both with regard to height and to girth; whilst, as regards total production of timber (inclusive of thinnings), there is no particular difference, although the proportion of branches is larger in plantations owing to the greater initial growing-space enjoyed by each individual stem. Whether or not the advantages as regards dimensions will be maintained by plantations up to the time of their fall as mature crops, is a question for the answering of which no data are yet available for a trustworthy comparison.

"It is no longer a matter of doubt or question that the rapid growth of many young plantations affects to a considerable extent the quality of the timber produced in comparison with what is yielded by crops formed by sowing, and that the former is less able to withstand the attacks of *fungi* later on.

"It must, however, be expressly stated that the rate of growth of young timber crops can afford no reliable indication for the future quality of the mature fall. Expectations, anticipations, and suppositions are not at all reliable, because so very much depends on the subsequent treatment of the crops (whether formed by sowing or by planting) during *the operations of thinning*" (Gayer, *Waldbau*, 1889, p. 384).

In estimating the profit likely to accrue from one or other of these methods of forming timber-crops, the initial cost, of course, forms an important factor. And, as planting is, on the whole, more expensive, often very considerably so, than sowing, a choice in favour of the latter method can generally be advised wherever special conditions of soil and climate do not indicate any necessity for planting. Where, however, the inexpensive method of *notching* can be carried out with very young seedlings without any special preparation of the soil, planting operations can frequently be undertaken just as cheaply as, or even cheaper than, sowing; and in all such exceptional cases planting deserves the preference. But the initial cost of sowing is apt to be miscalculated; and the subsequent filling in of blanks with transplants often brings up the actual cost to more than would have been the initial expense had planting been chosen as the original method of forming the crop.

Plantations have, in general, notwithstanding the interference and disturbance that takes place before the plants have thoroughly established themselves, a more rapid development in youth, and especially a more energetic growth in height, than young crops resulting from natural regeneration; whilst those formed artificially by sowing occupy a position between these two. These results are explainable by the greater amount of soil-preparation connected with both forms of artificial production and reproduction, and, in the case of plantations, with the larger amount of individual exposure to light, air, and warmth, together with a less prolonged struggle with weeds and rank growth of grass.

The earliest means taken for growing Oak artificially in England during Queen Elizabeth's reign (see *Introduction*, p. 19) was the dibbling of acorns, and this was practised more extensively in King James I.'s reign "for raising of new woods" early in the seventeenth century.

Choice between Sowing and Planting.—Hard-and-fast rules cannot possibly apply as to the general advantages of sowing and planting. Concrete factors must in all cases be known and studied before any proper opinion can be formed. But certain broad natural principles apply as to soil and situation, organic and inorganic dangers, and cost of production. It is worth noting that in the great German forests the broad-leaved trees have always been reproduced to a far greater extent naturally than artificially, and that natural regeneration and sowing of conifers are now far more practised than was the case thirty or thirty-five years ago. In plantations the young trees habitually exhibit a far more marked tendency towards **forked growth**, and in certain other respects the quality of the timber is also not so good as in tree-crops formed naturally or by sowing. On very bare rocky places sowing seed will often produce trees where planting would be almost impossible without carrying earth there; but such woods can never be like plantations intended for profit.

When the seed of exotic conifers was dear (*i.e.*, formerly all seed but Scots Pine, and even that was dear before the days of railways and steamships), it is easy to understand why a decided preference was given to planting. This, so well suited to our damp climate, has now asserted itself so strongly as our national method that sowing is never likely to find much favour in forming new woodlands; but at the same time the British forester should know something of the Continental methods of sowing, which are therefore here briefly sketched.

Continental Methods of Sowing.—The sowing may either be *broadcast*, when the seed is scattered by hand, as equally as possible over the whole area, or it may be merely *partial* and confined to *strips*, or *bands* (either continuous or broken), or *furrows*, or *patches* of specially prepared soil on which the seed is sown by hand or by machine, either over the whole prepared surface or else merely on portions of it. *Dibbling* is the term applied to the sowing of large seeds (acorns and chestnuts) over the whole area or on prepared patches only, where each seed is carefully inserted by hand. Where seed is plentiful and cheap, and the soil is not apt to be soon overgrown with rank weeds, broadcast sowing is the cheapest method, provided always that the soil already forms a suitable seed-bed (as on recently ploughed land, thrown out of cultivation) or can be easily prepared by harrowing, and that the seedlings are of rapid growth, so as soon to outgrow risk of being choked by weeds. Partial sowings require only a portion of the land to be specially prepared, but on those the seed is sown thicker than in broadcast sowing over the whole area.

Seed-Tests.—Unless the seed can be collected locally by trustworthy persons, a certain germinative capacity should be stipulated for when purchasing it. There are many places in Germany, France, Switzerland, and Austria where samples of large consignments of seed can be carefully tested in this way. But for a small purchase, private tests are quite sufficient to ascertain the quality and see how this may affect the quantity of seed to be used in sowing. These consist in placing a certain number of seeds (50, 100, or more) in a *flower-pot* filled with fine earth, always kept moist and in a moderately warm room, or between two pieces of *flannel* or *filtering-paper*, likewise kept always moist and warm, or laying them on damp sand and covering them with a piece of thin felt (or flannel) and putting a *glass shade* over them. There are many other more elaborate contrivances, but the simplest are the best. And in all of them the results will be higher the greater the attention paid to maintaining a constant temperature of 60° to 70° Fahr., a constant degree of moisture, and a sufficiency of oxygen. These are the three chief factors determining successful germination of good seed, though a slight amount of shade is also beneficial. As a general rule, the larger the seed the longer it takes to germinate—the period varying from about two to four or five weeks. When sown in the open, the germination usually takes longer than in well-conducted tests (see table below). Seeds with hard outer shells like Ash, Lime, Hornbeam, Maple, Sycamore, and Hazel, which generally lie over for a year in the soil before germinating, are of course unsuitable for such tests. As the seeds germinate they should be removed, and their number entered in the account kept of the test, so as to ascertain the total percentage. Concerning the results of such tests Gayer (*Waldbau*, 1889, p. 283) remarks :—

Considering the state of the seed-trade nowadays, one is justified in expecting the following results in experiments made for testing the quality of seed delivered before it can be admitted to fulfil the description of "good seed." But the germinative percentages have only reference to well-conducted experimental tests :—

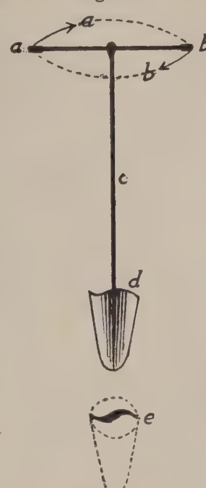
	Per cent.		Per cent.		Per cent.
Scots Pine	70-75	Cembran Pine	40-60	Ash	65-70
Austrian and Corsican Pine	75			Hornbeam	70
		Broad-leaved trees—		Lime	60
Weymouth Pine	60-70	Oak	65	Elm	45
Spruce, Norway	75-80	Beech	50	Alder, Common	35-40
Silver Fir	40-60	Sweet-Chestnut	50-65	Birch	20-25
Larch	30-40	Maple and Sycamore	50-60	Robinia	55-60

But, of course, when good seed comes to be sown out in the seed-beds, such high percentages can never be expected as are attainable in the case of experiments conducted under the most favourable conditions indoors ; and due allowance must be made for this shortage.

The average weight of seed per bushel, the number of seeds per pound weight, the fair percentage of germination obtainable in the open, number of seedlings obtainable from one pound, period of germination, and quantity of seed used per acre for sowing (*broadcast* and *partial*) on the Continent, is shown on p. 360 (as compiled from data by Klein, Lorey, the *Forst- und Jagd-Kalender*, and Boppe et Jolyet[1]).

Soil-preparation of the seed-bed, advantageous for broadcast sowings (even if only done with a harrow), and essential for the success of partial sowings on strips or patches, favours germination through providing improved conditions as to moisture, warmth, and oxygen. Strong sunshine is not favourable, while drought and frost are always dangerous to the young seedlings. Areas to be sown broadcast should first be burned over, if possible; while for partial sowings the strips, bands, and patches must at any rate have the soil-covering (weeds, moss, dead leaves, &c.) removed, and the upper surface of the soil broken up to a greater or less depth by either ploughing, digging, hoeing, or raking, according to its consistency and the necessity there exists for making it more porous and permeable. The breadth of these prepared strips or bands (which should, of course, run horizontally on sloping land, to prevent washing away of soil) is usually 1 to 1½ ft., with a distance of 3 to 5 ft. in between. Patches are usually about 1 ft. square, and 3½ to 5 ft. apart. Where smaller patches are wanted for dibbling, they can be made very quickly and cheaply with a *spiral spade* (Fig. 28), a strong iron instrument which works up the earth in a conical hole when forced into the soil and turned round.[2] Stiff soil should be prepared in autumn, to let it weather during the winter; but the opening up of light porous soil should only be undertaken shortly before the sowing takes place (either in autumn or spring).

Fig. 28.



Spiral Spade.

ab. Long wooden handle (giving leverage).
c. Iron shaft.
d. Spiral blade.
e. The hole prepared on spade being forced into soil and turned round from *a* to *b*.

The covering of earth to be given to the seed to protect it against heat, cold, and animals, depends on the size of the seed. Small seeds require a very slight covering of soil (Elm, Birch, and Alder only need firming on the ground; Larch, Scots Pine, and Spruce only ⅛ to ¼ of an inch), while the deepest covering (of about 1 inch) is needed in the case of Oak and Sweet-Chestnut. Not only are these and Walnut our largest seeds, but they all three (as also Hazel) leave their cotyledons under the ground-surface when they germinate, and therefore have not the same amount of *mechanical resistance* to overcome as Beech and other kinds of trees in pushing their seed-leaves up into the open air. On light soil the covering may be rather more than on stiff soil.

Time of sowing.—Except in the case of seed that rapidly loses germinative power (Elm ripening in May and June, Birch in July and August, and Silver Fir in

[1] Of course these data can only be rough generalisations, as great variations are caused by soil, situation, quality of seed, weather, &c.

[2] This good practical instrument for preparing a bed for acorns or Beech-nuts, &c., or making pits for small plants, the twisted **Spiral Spade**, is about 8 to 9 in. long and 5 or 6 in. broad, S-shaped at the top, and running to a point below. To give greater purchase it is provided with a long wooden crook, passing through an iron staple at the top of the iron handle; and by turning this the soil is broken up a good deal, and can easily be removed for crumbling up and replacing in the hole. A man can make from about 40 to 80 holes in an hour, according to the nature of the soil (Ney, *Waldbau*, 1889, p. 306).

Kind of tree.	1 bushel (of 8 gallons) of seed weighs about	1 lb. contains about	A good, fair, germinative capacity is	Average number of plants obtained per lb. of clean seed.[1]	Time seed takes to germinate in the open.	The amount of seed required for *broadcast* sowing over the whole area is, per acre,		For *partial* sowings.	Average cost of sowing.
	lb.	seeds (clean).	per cent.		weeks.	bushels.	lb.		
Oak, Pedunculate	63-90	125	60	75	4-6	8-16	450-900	*Note.* The quantity of seed required for *partial* sowings in furrows, patches, strips, or bands *varies from about* ½ *to* ⅔ of that required for broadcast sowing over the whole area, according to the proportion of the area actually sown.	*Dibbling acorns,* in rows 5 ft. apart, per acre=1·6 days of one man's work.
" Sessile		150		90					
Beech	40-45	2,000	60	1,200	3-4	3½-7	135-270		
Ash	14-15	7,200	50	3,600	4-6	3	36-45		
Maple, Sycamore	11-12	6,800	50	3,400	4-6 (and partly in second Spring)	3½-4½	36-45		
Elm	5	60,000	20	12,000	2-3	7-8	27-36		
Sweet-Chestnut	...	110	60	66	3-6	...	...		
Birch	8	800,000	10	80,000	4-5	4½	27-36		
Alder	27	360,000	15	54,000	3-6	⅗-⅘	13-18		
Hornbeam, rough	9	...	50	6,500	often only in second Spring	6-7	54-63		
Hornbeam, cleaned	43	13,000				over 1	30-45		
Larch, rough	15	...	40	...	3-5	1½	20		*Sowing Scots Pine-seed* in drills, per acre = 0·8 of the day's work for one man.
Larch, cleaned	45	72,000	35	25,200		½	13-18		
Scots Pine, rough	12-13	...	60	...	3-6	over 1	12-13		
Scots Pine, cleaned	45	75,000	50	37,500		1/7-1/6	5-7		
Spruce, rough	16	...	60	...	4-6	over 1	13-18		
Spruce, cleaned	50	64,000	50	32,000		about ¼	7-11		
Silver Fir, rough	18	...	50	...	3-6	3½-4½	55-70		
Silver Fir, cleaned	24	10,000	40	4,000		2-3	45-54		
Austrian Pine, cleaned	21	26,000	65-70	17,500	2-4	...	...		
Weymouth Pine, "	...	27,000	40-50	12,000	3-4	...	...		
Douglas Fir, "	...	40,000	...	...	3-4 (and partly in second Spring)	...	...		
Menzies Spruce "	...	300,000	...	...	...	...	...		

Note.—The price of seed varies from year to year, but the following quotations are the latest for Conifers, taken from the catalogue of the well-known Copenhagen firm, Rafn:—

Kind of seed.	Per lb. s. d.	Kind of seed.	Per lb. s. d.	Kind of seed.	Per lb. s. d.
Larch, Alpine	2 8	Scots Pine (Finland)	3 4	Spruce	2 0
" Silesian	2 10	Corsican Pine	2 6	White Spruce	6 0
" Siberian	5 8	Austrian Pine	5 6	Silver Fir	1 0
" Japanese	11 0	Mountain Pine (Denmark)	2 0	Douglas Fir	11 0

[1] These figures in column five should be compared with those of Brown's table giving the results of British operations twenty years ago (see p. 371).

autumn), the sowing can take place either in autumn or spring. But fresh seed must always be used, as many seeds (Oak, Chestnut, Hazel) lose their germinative power in about six months, while it is always more or less weakened in all other seeds, which then sometimes do not come up till the following spring after sowing. In *autumn sowings* much of the seed usually gets eaten by mice, squirrels, and birds, and many of the young seedlings that come up in early spring are killed by frost; so that on the whole *spring sowing* is preferable, even although this retards the time of germinating, and means that many of the seed only sprout one year afterwards, while many more lose their germinative power entirely.

It is best *not* to attempt to force on germination of the seed by soaking it in water a few days before sowing, as can be done with advantage in nurseries. This not only makes the seed more difficult to sow anything like evenly, either broadcast or in lines or patches, but if very dry or cold weather sets in after the seed has been put in the ground, the seed is much more likely to rot or lose germinative power than if it had been sown in its natural condition.

When planting has been decided on, the necessary supply of plants must either be obtained from *nurserymen* or else raised in *home nurseries on the estate*, the former being the cheaper way if only a small number of plants is required. Or a combination of both of these alternatives may be made by purchasing small seedlings and schooling them in *temporary nurseries* on part of the land to be planted, until they reach the required size.

Purchase of Plants from Nurserymen.—Only healthy plants should be selected, suitable for the soil and situation of the intended plantation. The forester should visit, during July or August when the plants are in full leaf, the nursery from which he intends to purchase plants, and should see that the stock is clean and healthy. The plants should be well-proportioned, of good healthy colour, and with large, prominent, well-formed buds. The mere height of the plants as quoted in nurserymen's catalogues is no criterion of quality, as the plants may have been drawn up by standing too close in the seed-beds or nursery-lines, or may have been forced on by strong manure. Thus stout, firm, one-year-old Larch seedlings of about 3 in. high are far better plants than tall drawn-up plants of 4 or 4½ in. with small poorly-developed buds. The outer cuticle of the bark should be easily removable with the finger-nail from the inner bark, which should be of a healthy green colour.

It is well to visit the nursery again in October or early in November (or in March for spring planting) when making the actual purchase, and only sturdy, well-proportioned, well-set, bushy plants with good, branching, well-fibred roots should be bought of the size required. The forester should himself superintend the lifting, packing, and despatch of the plants, as in the busy autumn season raw hands have often to be employed by nurserymen. To prevent wilting, the roots are often mulched in a loamy mixture before being packed in damp moss (see p. 384). In purchasing expensive ornamental plants, only those should be bought which have been hardened by growing in the open.

Training purchased plants in temporary nurseries.—If the young plants are bought while still small and cheap, they can be planted at from 8 in. to 1 ft. apart (43,560 to 98,010 per acre) on a suitable part of the land to form the new plantation; and when the plants have reached the size desired, $\frac{15}{16}$ to $\frac{35}{36}$ of them can be moved and planted out, leaving the remainder at 4×4 ft. Holes for receiving the plants can be made very cheaply with a spiral spade (see p. 359). Thus $\frac{1}{36}$ to $\frac{1}{16}$ of the land to be planted is stocked with young plants very closely; and if the area is extensive, several of such temporary nurseries can, at a comparatively small cost, be dotted at convenient parts over the whole land. This is an excellent method, because (1) it trains the plants on the soil they will have to establish themselves in; (2) it means the least possible distance in transport; (3) it enables planting to take place with fresh plants supplied every half-hour or hour, and to be interrupted whenever necessary (weather) or convenient (if men otherwise employed) without entailing any loss of plants; and (4) it is the cheapest method, as even the preliminary fencing is reduced to a minimum. This method has recently been carried out with marked success in the Forest of Dean, also in Hampshire, and elsewhere.

Private Nurseries are profitable and otherwise advantageous on any estate where extensive planting is about to be carried out.[1] Such nurseries may be either *temporary* or *permanent.* The comparative advantages and drawbacks of these have thus been well summarised by Lorey (*Waldbau*, in *Handbuch der Forstwissenschaft*, 1903, p. 481):—

Nurseries are of two classes—*permanent*, and *temporary* or *shifting.* The former are used continuously for a long time, the latter only for a short time so as to furnish plants for certain plantations. *Temporary nurseries* are, of course, formed as near as possible to the intended plantation, and when the planting is completed they are either given up again or else form part of the plantation. *Permanent Nurseries* cost more in the first instance (more careful soil-preparation, &c.), require manuring when the soil gets exhausted, and often lie further from the tract to be planted; but on the other hand, one saves the recurrence of first outlay (soil-preparation, fencing, &c.), as this is spread over a longer period of time, while they are easier to supervise, and permit of more thorough and extensive working, because, owing to the larger number of plants produced annually, one can afford to spend money on the best implements, on protective guards and screens, or even on irrigation, &c. Both kinds of nurseries find their practical uses; and whether the one or the other may be preferable, often depends upon the transport of the plants, especially when these are wanted with balls of earth around their roots. In this case it is advantageous to form *temporary nurseries* for seedlings and transplants near the area to be planted; but, on the whole, *permanent nurseries* are generally preferred, even although they may perhaps cost more.

Temporary Nurseries.—If desired, of course the seedlings themselves can be raised in one of such temporary nurseries (in the same way as in permanent nurseries, see below), or they may be taken from woods near at hand where seedlings are plentiful, and then (in either case) set in lines at 1 ft. apart till big enough for planting in the open. This method has the advantage of producing plants that should be well suited to the land to be planted, because

[1] Thus, for instance, on the Seafield estate at Strathspey, where upwards of 1,000,000 plants were required annually, there was a permanent nursery of about 12 acres, with a regular staff of nursery hands. This was found to supply cheaper and more suitable plants than could elsewhere be obtained (Brown *The Forester*).

there will be no variation in climate, and probably but little in soil and situation—or, at any rate, far less than is the case with plants brought from some distant nursery, where they have been grown under more or less forcing conditions (richer soil, manured, &c.)

The earliest and simplest form of temporary nursery was that for Oak seedlings; and even down to ninety years ago the following ingenious method was in practice (see Stevenson's *Agriculture of Surrey*, 1813, p. 438):—

The field in which it is intended to sow the acorns is completely summer-fallowed and entirely cleansed of all root-weeds, and has a good dressing of manure, and sometimes of lime, given it. At the last ploughing it is ridged up so as to keep it as dry as possible during the winter. Wheat is then sown in it at the usual season, and after the wheat is well harrowed in, acorns are put in with a dibble at about 1 ft. distant from each other. When the wheat is reaped in the ensuing autumn, the seedling Oaks are not sufficiently high to be cut by the sickle; the stubble serves as a kind of protection to them during the winter; and in two or three years after the acorns are put in the seedling plants are fit to be transplanted.

Of course that was in the days before rabbits were such pests as now, and before reaping-machines cut the stubble very short. It would be wellnigh impossible to raise plants in this unprotected way nowadays.

Various General Principles have to be borne in mind when forming a nursery, and especially an expensive permanent nursery. Of these the following are the chief (Lorey, *op. cit.*, p. 482):—

1. *Situation.*—The nursery should be as near as practicable to the places where the plants will be required, and within easy reach of the forester's supervision. Fairly level ground is best. Steep hillsides are generally unsuitable, a gentle slope being more desirable; but when either somewhat too damp or rather too dry a site cannot be avoided, then drainage or irrigation may become necessary. S. and S.W. exposures suffer from overheating and drought;[1] while E. and S.E. aspects are worst for frost (and E. in Britain for cutting spring winds). The shady side of old timber crops is usually, though not always, advantageous. Deep coombes should be avoided on account of frost, while water should be near at hand for watering (if necessary) during dry periods. Places in the interior of woodlands are preferable to those near the edge, because of mice coming in from the fields in autumn. Places with a strong growth of weeds should not be selected.

2. *Soil.*—There must be sufficient mineral strength combined with the necessary physical properties, and in particular it should not be too stiff (cold clay). Soil of medium consistency (sandy loam) is best, but a somewhat too light soil (sand) is preferable to one that is too heavy (clay). The subsoil should be examined to make sure that it is pervious to water.

3. *Size.*—This must of course depend on the number of plants wanted each year, the age at which they will be required, and whether seedlings or transplants are wanted. About $\frac{1}{25}$ to $\frac{1}{20}$ (4 to 5 per cent) of the annual area to be planted will suffice for supplying four-year-old conifer plants (two-year seedlings, two years transplanted).

4. *Shape.*—When practicable the nursery should be of rectangular form, as that costs least to fence (the square least of all), and is easiest to subdivide into compartments and beds. On sloping land the long side of the rectangle should

[1] The Continental climate is much drier than that of the British Isles; and what might be best suited for the N.W. of Scotland might be a bad exposure for the dry E. coast of Southern England.

run horizontally; otherwise the more important it is to have side-protection, the longer the rectangle should be.

5. *Soil-Preparation.*—The soil must be thoroughly trenched and cleared of stones and roots (especially of those like Aspen, which can throw out suckers). The comparative ease with which old field land can be prepared should not be allowed to influence the choice of a site, as such land is mostly exhausted and has a strong growth of weeds. The cultivation of a root-crop for one year prepares the soil well, but if it be given up to root-crops for several years, it then becomes more or less exhausted. Trenching should be done in autumn to let the frost mellow the soil; but if there be a heavy growth of weeds, trenching in early summer assists decomposition. Trenching usually requires to be done to a depth of 12 to 16 in. on the average. The ground should be levelled immediately after being trenched; and on steep slopes terracing may be necessary, because each of the beds should have a horizontal surface.

6. *The Physical and Chemical Properties of the Soil* sometimes stand in need of improvement. Wet patches must be drained. Heavy soil can be improved by deep trenching or by the addition of sand, while both very stiff and very light or poor land can be improved by growing a crop of lupine and digging it into the soil (see also p. 366).

The Practical Work of forming a Nursery may be briefly sketched as follows:—

1. **Selection of Site.**—Where practicable, **Nurseries** should be formed on land of fair medium quality. If the soil be plainly somewhat below the average in quality, the plants are not strong and vigorous; but if, on the other hand, the soil be rich, then they soon become predisposed to disease, and are also apt to **wilt** or droop when finally planted out on soil which cannot yield to them the same ample food-supplies that they have been accustomed to in the nursery. If the site be too much exposed to cold and cutting winds in spring, the young plants will also be impaired in their health and vigour; if surrounded by wet undrained land, there will be danger from late frost; if too much sheltered by trees, the young plants will be drawn up and weakly, and when planted will find difficulty in establishing themselves and beginning to grow; if lying to the east, the effect of the morning sun in April after a night's frost will be injurious; while if the aspect be north, the soil will be cold and inactive, and the period of vegetation will be late in commencing, less energetic while it lasts, and early in terminating. In choosing the site, therefore, let the soil be rather light than otherwise; let it either be fairly level or else have a gentle southern slope, and neither too much exposed nor too much sheltered; and let it be in rather a dry part of the estate.

2. **Size.**—As above indicated, practical experience shows that for raising a stock of strong four-year-old conifer plants (two-year seedlings, two years transplanted) about $\frac{1}{25}$ to $\frac{1}{20}$ (4 to 5 per cent) of the annual area to be planted is required for nurseries, and the higher limit also makes fair provision for the schooling of a due proportion of broad-leaved plants, which (like Larch) take up more room than Pine, Spruce, Douglas Fir, and Silver Fir. Thus, supposing about 600,000 plants of various sorts, chiefly conifers, are annually required for planting 200 acres at 4 × 4 ft. (2722 per acre × 200 = 544,400, allowing for

55,600, or about 10 per cent, being unsuitable plants), then the nursery would require to be from 8 to 10 acres in area, which would be most conveniently laid out in the form of a rectangle (with sides 10×8 chains, or $12 \times 6\frac{2}{3}$, or $15 \times 5\frac{1}{3}$, or $16 \times 5 = 8$ acres, and 10×10, or $12 \times 8\frac{1}{2}$, or $15 \times 6\frac{2}{3}$, or 20×5 chains $= 10$ acres), with the long side running horizontally.

3. **Soil-Preparation** is often necessary, and always advantageous. A suitable site of, say, 8 to 10 acres having been selected and marked out, the next step is to prepare the soil.

If drainage is necessary, all the drains should be made to empty into a deep well on the lowest part of the site, to supply the nursery with water lifted by a pump. But there must be an escape-drain from the well to permit of water flowing off when it rises to within 5 ft. of the ground-level.

After being drained, the land should be trenched to a depth of 2 ft., and all stones should be removed down to the size of a hen's egg; for the fewer stones there are left, the better can the subsequent operations be performed. In trenching, the land should be levelled as far as its general surface requires. To leave the levelling to be done after trenching is not economical, because some parts may have to be lowered, and would therefore be poor and unproductive as compared with the parts where soil was added.

The draining and trenching should be done in late summer, so that in November the land may be ploughed, and then left to weather under the action of the winter frost and rain. During the following spring it should be again ploughed, or at any rate harrowed and raked, to make the surface fine, and all remaining stones then found should be removed.

4. **Manuring.**—A nursery must on no account be kept in a highly manured state, otherwise the young plants are unduly stimulated; and when removed thence to a poorer soil, they wilt and droop, fail to establish themselves, and often ultimately become impaired in value as timber crops. A new nursery may, however, perhaps require one dressing with manure when the land is freshly trenched, as in this state there seldom exists much *humus* or vegetable matter in the newly turned-up earth. But it is usually better to use good leaf-mould, compost-earth, or wood-ashes than stable manure or still richer artificial manures. The former class contains enough of the essential ingredients required for fertilising (*nitrogen*, *phosphoric acid*, and *potash*), and their action can be increased by adding *lime*, which is of itself beneficial, both chemically and physically, and which is withdrawn from the soil by plants to a far greater extent than any other mineral (see chap. i. p. 307). Later on the beds may be manured entirely with well-rotted weeds, leaves of trees, or turf, and fresh soil carted from old fences or the boundaries of fields, with a slight admixture of lime to facilitate decomposition and humification. A part of the nursery may very conveniently be set apart for preparing such light manure; and as the properly humified portions are laid on the seed-beds or nursery compartments, fresh quantities are collected for successive use. Weeds should be thrown into the manure-pit before they seed; otherwise they should be burned, to prevent the seeds germinating on the beds manured later on.

In French nurseries, *humus* or compost is prepared in the following cheap and practical manner (Boppe et Jolyet, *op. cit.*, p. 358) :—

Outside the nursery, but as near to it as possible, and giving the preference to well-sheltered places, a trench is dug 24 to 32 in. deep and 10 to 13 ft. broad, and the bottom is given a convenient slope towards an off-flow ditch so that water may never lodge. Into this rotting-pit are thrown dry leaves collected in autumn at the time of their fall, preferably during damp weather, and heaped together. All the nursery rubbish is also thrown in — weeds, non-lignified shoots, moss, straw, turf, ashes ; *but the greatest care should be taken never to throw into this rubbish-pit plants which have already flowered.* As soon as a weed has set seed it ought to be burned, otherwise it is sown again with the compost.

To stimulate decomposition, the heap should be turned twice a-year, usually in May and September, when work in the nursery is least pressing, and time can be spared for adding suitable chemical fertilisers. On the average it takes three years to produce thorough humification.

The length of the ditch depends on the quantity of compost required annually. The main points to be kept in view are that this rubbish-pit should always be able to provide (1) a vacant space for the dead foliage gathered in autumn, (2) a heap of leaves that have lain for one year, (3) another that has lain for two years, and (4) the three-year-old compost ready for use. Care should be taken to have these various sections separated by a sufficient space between each two to permit of the heaps being turned over with the shovel.

During dry weather the rubbish should be watered from time to time, and the waterings are more efficacious if liquid manure, sewage, lye, soap-suds, kitchen washings, or liquid guano be added. All compost, no matter whence procured, should be passed through a screen before being used.

If a sort of rotation be made of the nursery-beds, so that after a year or two of raising Conifer plants the beds may be used for broad-leaved stock, and *vice versâ*, this prevents any one mineral ingredient becoming prematurely exhausted. Or a bed where two- to three-year-old Oak have been suffering from the root-fungus *Rosellinia quercina* can be used for Conifer transplants for two to three years ; or *vice versâ*, where Pine foliage has been attacked by the leaf-shedding fungus (*Leptostroma pinastri*), the beds should for the next four years be used for other kinds of plants. But there will always be compartments on which the plants are to be put out in spring, and which will lie fallow till the autumn or following spring. Such may be strongly manured and sown with any summer grain crop considered best for the district, and after the crop is reaped it should be trenched in September or October to rot the stubble and improve the land before the seedlings are bedded out on it in autumn. Or if not needed until the spring, a root-crop may be sown. This both improves the land, keeps it free from grubs, and is a profitable way of using land that would otherwise lie fallow.

A good method of stimulating the productivity of nursery-ground to a desirable, and not excessive, extent is to sow a crop of lupine, and then, instead of removing it for fodder when ripe, to dig it into the soil and allow it to humify. This plan is adopted with very satisfactory results on the poor sandy soil of the North German plain, where, even in producing Scots Pine chiefly, the nursery-ground soon requires stimulation. Like all other leguminous plants (vetches, lucerne, beans, &c.), lupine has the power of laying up stores of nitrogenous products in the root-nodules by the symbiotic aid of a bacillus ; and, on humification, these and other food-supplies are returned to the soil in a form readily available for imbibition by the rootlets and suction-hairs.

The Continental system of collecting heaps of good soil, leaves, turf, grass, and weeds here and there in the woods, and turning them over from time to time so as to assist in their decomposition, provides a milder and more humose compost for nursery purposes than stable-manure rich in salts of potash, phosphates, and nitrates. The latter, in fact, very closely resembles artificial manure in its action, concerning which the following remarks are specially applicable (Gayer, *Waldbau*, 1889, p. 326) :—

> Where artificial manures are used, it must be borne in mind that they are usually rapid in action, and when used in excess are injurious to woody-fibrous plants ; hence more than about 1¼ to 1½ cwt. per acre should not be added. But wherever their use is considered desirable, it is a good rule to apply them only alternately with the above-mentioned milder forms of manure (*i.e.*, *humus* formed of leaves), so that an application of mineral fertilisers may be succeeded in a few years by a dressing of woodland soil, leaf-mould, compost, &c., and then again artificial manure, and so on.

5. **Fencing.**—If not previously fenced, the land should now be enclosed by a substantial fence, such as a wall, stone dyke, hedge, wooden paling, or wire fence. Whatever kind of fence seems preferable, it must be made proof not only against horses, sheep, and cattle, but also against hares and rabbits as well.[1] Wire-fencing gives no protection from wind. If the situation be exposed, a good wall or high thick hedge is necessary, while smaller hedges may be desirable within the nursery to act as screens to protect the seed-beds and nursery-lines. To keep out deer and cattle, the fence is better if surrounded by an outer ditch, on the top of the output from which the line of fence is made to run.

6. **Laying out of Nursery-Beds** is easy enough in a square or rectangular nursery, but if the sides are curved or of unequal length, it is difficult for the men to keep their seed-beds and transplant-lines parallel with the paths and roads, and then the nursery assumes an untidy appearance.

The first thing to do is to divide the whole area into main rectangular sections by a network of roads 8 to 10 ft. broad, which will permit of carts being taken to every part of the nursery. These main sections are divided into plots of about ¼ to ⅜ of an acre (*i.e.*, 1210 to 1815 sq. yards, whose sides will be more or less in proportion to those of the whole nursery) by means of paths of about 3 ft. wide, along which a wheel-barrow may easily be taken. These are again subdivided into beds of 3½ or 4 ft. wide, with footpaths about 1 ft. broad in between, from which the workmen can easily reach the middle of the bed without treading on it. These roads, paths, and footpaths altogether take up from about ¼ to ⅓ of the whole area (or about 2 to 2½ acres in an 8-acre, and 3 to 4 acres in a 12-acre nursery).

Whatever the area of the nursery may be, about one-tenth of it will usually require to be devoted to *seed-beds* for raising *seedlings*, and about nine-tenths to *nursery-lines* for pricking out and schooling *transplants*.

[1] Details as to fencing will be found in vol. ii., Part IV., *Protection of Woodlands*, chap. ii.

The soil removed from the roadways and paths should be spread equally over the beds, as this helps to keep them dry and well-drained after heavy rain. In laying out the cart-roads, they should be sunk deep enough (usually about 1 ft.) to obtain a fairly hard base for laying road material, and broken stones or rough gravel should be carted and laid regularly to a thickness of 8 in. or more. The roads should then be edged with Privet to prevent earth falling down into them, and to give a neat appearance, and then top-dressed with gravel.

Privet is perhaps the best plant for this purpose, as it is not so easily injured as Box and other plants if trodden on or driven over. For this purpose **one-year cuttings**, generally about 12 in. high, may be used.

Unless good hard gravel be used the roads will be soft and unserviceable in autumn and spring, and difficult to keep free of weeds in summer. The upper layer of gravel should be put on 4 in. deep on the sides, and about 6 in. deep in the middle, so as to secure a slight drainage-fall from the middle to each side.

7. **Stocking the Nursery.**—The nursery-ground will now be ready for the seed to be sown on the seed-beds and the seedlings to be put in the transplant-beds.[1] During the first year it will be necessary to buy young plants of the various kinds to be used in the following year, and to have a stock on hand for use until home-grown plants have been raised from seed. These are of course pricked out in the transplant-beds in the same way as seedlings of a like age (see below).

(1) **Sowing on the Seed-beds.**—If the seed-drills are to run the long way of the bed, the simplest way of forming them is to stretch the line from end to end at about 3 or 4 in. from the edge, and make a drill with a hoe to the required depth for the given kind of seed. On this drill being sown, the line is moved to the required number of inches (4 to 6 or 7 in. should suffice for most plants that are to be pricked out in the transplant-lines as one-year-old seedlings, while 6 to 7 in. is enough for Pines and Firs to be planted as two-year-old seedlings), and a second drill made parallel to the first; and so on till the $3\frac{1}{2}$ or 4 ft. broad bed is filled.

Another method sometimes practised in Germany is to roll the bed lightly with a roller (of the same breadth as the beds) having raised ridges, which press into the soil and at once make the parallel drills at the required distance. Such rollers are made with adjustable sections, so that one can vary the distance from drill to drill.

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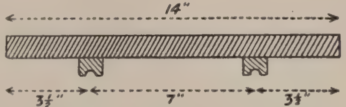
[1] **The Nursery Implements** required are the ordinary garden tools. There should be rakes of various sizes, including large wooden *harrow-rakes* with heads about 24 in. long and teeth 4 in. long and 3 in. apart, *medium-sized iron rakes* about 18 in. in the head and with 3-in. teeth and 2 in. apart, and *small rakes* of 12 in. in the head and with teeth $1\frac{1}{2}$ in. long and 1 in. apart, which are all required in bringing the earth to a fine mould. Good garden-lines on reels are also needed, besides a 12-ft. measuring-rod, well marked in feet and inches, and measuring-sticks of 4 ft. long, marked in inches, for setting out parallel drills and lines on the beds. After digging, the harrow-rake, medium-sized, and small rakes are successively used, so as to pulverise and thoroughly prepare the earth for receiving the seed.

If, however, it be preferred to have the drills run across the bed, then they can very easily be made by simply pressing the ½-in.-thick side of the 4 ft. measuring-stick into the soil to the required depth, taking care, of course, to make all such short cross-drills parallel to each other and at right angles to the long side of the bed.

Special contrivances are also in use on the Continent for making two or more of such short cross-drills at once. One of the simplest and best is the *Bavarian drill-board.* This consists of a thick board as long as the bed is broad (3½ or 4 ft.), with projecting pieces of wood (of the size and depth the drill is desired to be) screwed on to it at one-fourth the width of the board from each side. Say, for example, the breadth of the beds is 4 ft. and the drills are desired 7 in. apart, the board would here be 14 in. broad (Fig. 29), and the projecting pieces of wood (say, 1 in. deep and ¾ in. broad) would be fixed at 3½ in. from each edge, leaving a space of 7 in. between. Each time the board is moved forward on the bed, the 3½ in. left at one side where the board has already been pressed down, and the 3½ in. on the other side when it is placed in the next position, make up the 7 in. from drill to drill. Similar boards can easily and very cheaply be made, suitable for other distances from drill to drill (6, 8, 9, 10, or 12 in.) As the drill formed has this shape , the seed poured in falls to right and left, and thus gets better distributed.

Fig 29.



[*Cross-section of a Bavarian drill-board, intended to make drills 7 in. apart.*

Or, on the same principle, three or four drill-battens can be ranged in parallel lines at the desired distance, and held in position by being screwed firmly on to three to five crossbars on the top. This makes the frame lighter and easier to handle than if the whole top-piece were a ¾ or 1 in. board.

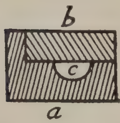
The covering of earth to be given to the seed is much the same as in ordinary sowing (see p. 359). But in the nursery this can be done more carefully; and in the case of broadcast sowings it may be given by passing fine earth through a sieve all over the bed till the required thickness has been attained.

Germination of the seed can be hastened by soaking the seed in water a few days before sowing; and this shortening of the latent period diminishes risk from birds, &c. But if the time of sowing is followed by very dry or cold weather, the seed-beds may have to be watered, else a good many of the seeds rot.

Care should be taken not to sow the seed too thick, and more especially if the seedlings are intended to be transplanted into the nursery-lines only at two years old, or perhaps not at all. In this latter case, broadcast sowing over the whole seed-bed is preferable to drill-sowing, as the seedlings form a better root and crown; but there is greater difficulty in keeping the beds clear of weeds, the plants are more easily lifted by frost, and young conifer seedlings find greater difficulty in forcing their way out of the ground when the surface becomes slightly caked. Sowing in drills is therefore the general practice. If broadcast sowings are found to come up too thick, the plants should not be thinned by plucking out, but by cutting narrow bands with a pair of small shears, thus leaving rows of seedlings as if they had been sown in drills.

Various mechanical contrivances are in use on the Continent for ensuring a more equal distribution of seed in the drills than can be attained by hand. One of the simplest of these arrangements is Cardot's *seed-distributor* (Fig. 30), made of the same length as the Bavarian drill-maker, and intended to be used along with it. This consists of a piece of wood (*a*) as long as the seed-bed is wide ($3\frac{1}{2}$ or 4 ft.), with a longitudinal groove (*c*) of sufficient width and depth to hold the exact quantity of seed which it is desired to sow. The seed is kept in place by a sliding top-piece of wood (*b*); and when it is desired to empty the seed into the drill, the whole is turned upside down and placed exactly over the drill, and the top-piece (now resting on the ground) is withdrawn at the end to allow the seed to fall into the drill.

Fig. 30.

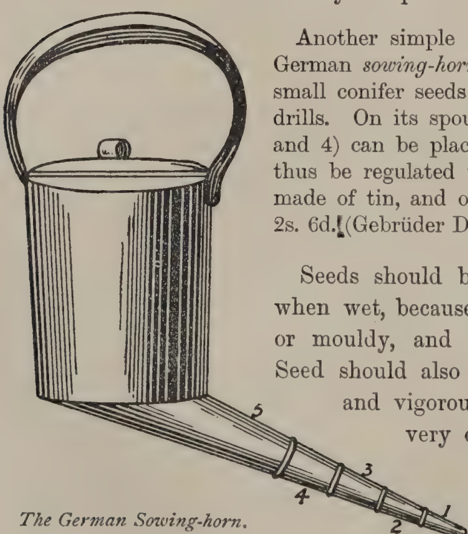


Cross-section of Cardot's Seed-distributor.

a. The grooved piece of wood.
b. The sliding top-piece.
c. The groove for holding the seed.

It is, of course, necessary to have several of such distributors, with grooves varying in width and depth to suit the requirements in sowing different kinds of seed. And for economy and ease in making them, *a* can be made of two pieces of wood nailed together (the grooved base and the upright back piece), in place of only one piece.

Fig. 31.



The German Sowing-horn.

Another simple and practical contrivance is the German *sowing-horn* (Fig. 31), chiefly used for sowing small conifer seeds (Pine, Spruce, Larch) in nursery-drills. On its spout (5) four smaller nozzles (1, 2, 3, and 4) can be placed, so that the issue of seed can thus be regulated to five different quantities. It is made of tin, and one containing $2\frac{3}{4}$ lb. of seed costs 2s. 6d. (Gebrüder Dittmar, Heilbronn, Würtemberg).

Seeds should be gathered while dry, and not when wet, because damp seed is apt to get heated or mouldy, and to lose in germinative power. Seed should also be gathered only from healthy and vigorous trees, neither very young nor very old; because a large proportion of the seeds from young trees are immature, while those from very old or diseased trees are wanting in vitality after germination. Only the best seed that is available should be used, otherwise the plants obtained will be fewer in number and inferior in every respect to those grown from the seed of middle-aged trees in full health and vigour.

For drill-sowing of small seeds, the usual quantity sown in British nurseries per sq. pole ($272\frac{1}{4}$ sq. ft. $= \frac{1}{160}$ acre) of seed-beds is—

Ash, Maple, Sycamore, ¾ to 1 lb.
Elm and Hornbeam, about ½ lb.
Birch and Alder, 1 to 1½ lb.
Scots Pine, about ½ lb.
Spruce, about ⅔ lb.
Austrian Pine, about ¾ lb.
Larch, 1 to 1¼ lb.
Silver Fir, about 2½ lb.

The quantity of seed formerly sown in nurseries in Britain, and the average number of seedlings produced, were as follows (Brown, *The Forester*)[1]:—

Kinds of Trees.	Time of ripening of seed.	Quantity of seed.	Manner of sowing.	Number of seeds in the rows.	Depth at which seed should be sown.	Number of seedlings that may be expected.	Age of transplanting from seed-beds to nursery-lines.
Broad-leaved Trees.							
Oak	November	1 bush.	In rows 15 in. apart	1 to every 3 in.	1 to 1½ in.	6000 to 8000	1 year
Beech	Oct., Nov.	1 bush.	In drills 8 to 10 in. apart	1 to every 2 in.	½ to ¾ in.	10,000 to 12,000	2 years
Ash	Oct., Nov.	1 bush.	In drills 12 in. apart	1 to every 3 in.	¼ to ½ in.	12,000 to 16,000	1 year
Maple and Sycamore	October	1 bush.	In drills 10 to 12 in. apart	1 to every 3 in.	½ to ¾ in.	10,000 to 15,000	1 year
Sweet-Chestnut	Mostly imported	1 bush.	In drills 18 in. apart	1 to every 4 in.	1½ to 2 in.	3000	1 year
Horse-Chestnut	October	1 bush.	In drills 18 in. apart	1 to every 4 in.	1½ to 2 in.	2000 to 3000	1 year
Walnut	October	1 bush.	In drills 18 in. apart	1 to every 4 in.	1½ to 2 in.	4000 to 6000	1 year
Elm	May, June	1 bush.	In drills 10 to 12 in. apart	1 to every 2 sq. in.	⅛ in.	5000 to 7000	1 year
Alder	Oct., Nov.	1 lb. of clean seed	In beds	1 to the sq. in.	⅛ to ¼ in.	5000	1 year
Birch	October	1 bush. of clean seed	In beds	200 to the sq. ft.	⅛ in.	15,000 to 18,000	1 year
Conifers.							
Scots Pine	Nov., Dec.	1 lb.	In beds	2 to the sq. in.	⅛ to ¼ in.	7000 to 10,000	1 year
Larch	November	1 lb. home seed,	In beds	2 to the sq. in.	⅛ to ¼ in.	2000 to 3000	1 year
"	"	1 lb. foreign seed	"	"	"	6000 to 9000	"
Spruce	November	1 lb.	In beds	2 to the sq. in.	⅛ to ¼ in.	8000 to 10,000	2 years
Silver Fir	November	1 lb.	In beds	2 to the sq. in.	¼ to ½ in.	About 500	2 years
Pinaster	Mostly imported	1 lb.	In beds	1 to the sq. in.	½ to ¾ in.	500 to 800	1 year
Hedge Plants.							
Hawthorn	November	1 bush. of clean seed	In beds	1 to the sq. in.	¼ to ½ in.	15,000 to 18,000	2 years
Holly	November	1 bush. of clean seed	In beds	1 to the sq. in.	¼ to ½ in.	15,000 to 20,000	2 years

Continental Sowings.—*In Germany* the average quantity of seed sown on seed-beds amounts per *are*, or 4 square poles or perches (*i.e.*, on $\frac{1}{40}$ of an acre), as follows, though varying, of course, according to soil and situation, quality of seed, weather, &c. (*Forst- und Jagd-Kalender*):—

	lb.		lb.
Oak	18-36	Larch	3½-4½
Beech	21-42	Scots Pine	1¾-2½
Ash, Elm, Maple, and Sycamore	3½-4½	Spruce	2¼-3½
Hornbeam	2¼-3⅓	Silver Fir	18-26
Alder	4½-8½		
Birch	up to 2		

[1] These results should be compared with what is the average number of seedlings obtained per pound weight of seed on the Continent (see column 5 of table on p. 360). They are very far below the ordinary average Continental results.

In France (Boppe et Jolyet, *Les Forêts*, 1901, p. 378) :—

For sowings made in seed-beds intended to be broken up after the second year, it is sufficient to employ, under average conditions as to soil and climate, the following quantity of seed for every 1000 running mètres (1100 yards) of seed-drills :—

	lb. (clean seed).		lb.
Spruce	13-15	Ash	66
Scots Pine	11-13	Maple and Sycamore	66
Larch	15-17	Elm	26
Austrian Pine	17-20		
Silver Fir	66-77		

If the seed-beds are to be broken up after the first year, these quantities should be increased by one-third.

One reckons for every *are* (*i.e.*, 4 square perches or $\frac{1}{40}$ of an acre) from 600 to 700 running mètres (660 to 770 yards) of seed-drills at 6 to 7 in. apart, including a deduction for 1 ft. paths between beds of 5 ft. in breadth.

The following notes on the sowing of different kinds of tree-seeds are condensed from Brown (*The Forester*) :—

Oak.—The acorns should be carefully selected, otherwise the plants will be weakly. The larger the acorn, the stronger and healthier the plant produced, and the better the class of timber. The acorns should be collected from middle-aged but still healthy trees that have not yet begun to show signs of senile decay. Seed from young trees, although of fair size, does not produce strong healthy plants ; and seed from very old trees is small and inferior. The requisite quantity of acorns should be collected in dry weather late in October or early in November, and should be brought in open baskets, or in bags if the distance is great, and stored thinly on the floor of a loft till the desired quantity is obtained.[1] Meanwhile the piece of ground on which they are to be sown should be prepared by

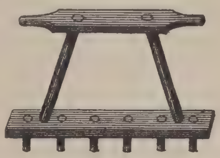
[1] In Germany they are frequently stored in the following way :—

Winter Storage of Acorns.—The main points to be kept in view in storing acorns are (1) to prevent them from germinating too early or from becoming overheated and losing their germinative power, and (2) to avoid drying them so far as to cause them to rattle in their shells. The danger of premature germination is less in the case of the Pedunculate than the Sessile Oak, whose smaller acorns are more difficult to store safely through the winter months. Whether the acorns are to be stored throughout the winter, or merely for a short time pending despatch to some other part of the country, the best plan is to spread them out on dry airy places and turn them frequently with a rake, or with a shovel if in high heaps. When frosty weather begins to come, they should then be stored in broad ditches about one foot deep, made in dry airy places, the output from which is ranged round the storing-place to prevent rain from entering. Above this a roof of thatch, straw, furze, reeds, &c., should be erected just high enough to let a man get underneath to turn over the acorns with rake or shovel occasionally to prevent their getting overheated. To facilitate this operation, the ditch and the roof-covering should be made somewhat longer than is absolutely required for the quantity of acorns when filled up to a depth of about a foot. The shifting in the position of the vacant space at each end at the same time forms an excellent means of control when orders have been given for airing the acorns. So long as there is no hard frost, the ends of the roof-covering may remain open for the circulation of air ; but in severe weather it is better to close them up with straw or material similar to that of which the roof is composed, and if necessary the roof itself should be thickened. When warm spring weather sets in before it is thought prudent to sow the acorns, the doors or coverings at the end may be closed again, and ventilation effected chiefly by means of small holes in the roof, which must of course be closed during wet or very cold weather. Before sowing the acorns in spring, their quality should be tested ; this can easily be done by making transverse sections of a few of them. If steeped in water before being sown, those that float on the surface should be put aside as not likely to yield satisfactory results (Burckhardt, *Säen und Pflanzen*, 1893, pp. 52-55).

digging thoroughly and raking to a finer mould. The acorns should then be sown in parallel rows 15 in. apart. The line being stretched from side to side of the compartment where the first row is to be sown, the acorns, held in an apron, are dibbled in about 1 to every 3 in. When the first row has been sown, the line is moved 15 in. distant from, but parallel to, its first position; and the dibbling is thus continued in lines till all the bed has been sown. A soil-covering of 1 to 1½ in. of good mould should then be given from the soil between the rows of acorns. It is preferable to do this with the spade rather than with the rake or hoe, because, when the latter are used, many of the seeds are displaced and come up irregularly. But when the acorns are covered, the earth should be smoothed with a fine rake without disturbing the seed by deep raking. By sowing the acorns on the surface and taking the mould from between the rows, the seeds lie on a dry bed all winter, and are more likely to germinate well in spring and ripen their wood thoroughly before the season closes in autumn, than if they are sown in drills.[1]

The following is the Hanoverian method (Burckhardt, *op. cit.*, p. 77):—

Fig. 32.



Acorn-dibbler.

> The seed-drills, which are made with the hoe to a breadth of 3 to 4 in. along the line, should be 18 in. apart at the very most, and ought to be closer if early transplanting be intended. Instead of strewing the acorns in these drills, they should be laid in the rows at regular intervals of about 3 in. apart, and the rows can be made closer together. The **acorn-dibbler** (Fig. 32) can also be advantageously utilised in dibbling the seed in lines about 1 ft. apart.

Beech.—The seed ripens freely in most seasons, and is easily gathered as the beechnuts fall from the trees in October and November. It should be mixed with sand and preserved for sowing out in March. It should be sown thickly in lines from 8 to 10 in. apart, and about 2 in. in breadth and depth, and covered with ½ to ¾ of an inch of earth. Beech-seed is very hardy, and germinates freely; but the plants are small at first, and need to stand two years before they are fit for the nursery-rows.

Ash.—The seed having been gathered from healthy trees in October, the seeds should be mixed with dry sand and kept for eighteen months to rot off the outer coat; and to ensure this the whole mass of seeds and sand should be turned once every three months, otherwise it is apt to get heated. In the second March after collection it should be sown in rows about 12 in. apart, one seed to every 3 in., and covered with only from ¼ to ½ an inch of earth.

Elm.[2]—The seed must be collected before it falls in June. It must at once be sown in drills about 10 to 12 in. apart, and covered with only about ⅛ in. of soil. The soil should be made as fine as possible; and the soft easily injured seed should be sown on a dry day, when the earth does not stick to the seeds, as this tends to rot them.

Alder.[2]—The seed should be collected early in spring, sown thickly in March on finely prepared earth, in beds about 4 ft. broad, and given a covering of only ⅛ to ¼ of an inch of earth.

Birch.[2]—The seed is sown like Elm and Alder; but it is very small, and does

[1] The Burmese method of sowing Teak-seed only when it has begun to germinate might quite well be adopted for large seed-like acorns, Chestnuts, and Walnuts. If these were sown very thickly on the top of fine soil (in a spot protected from frost) and kept with a top-covering of damp moss, the seed could immediately on showing the sprout be at once sown at 3 by 3, 3 by 4, or 4 by 4 in seed-beds (so that there would be no blank spaces), and allowed to stand there till wanted for transplanting or planting.

[2] When only small quantities of Alder, Birch, and Elm seed are to be sown, it is convenient to raise all three kinds of seedlings on one bed, as they require much the same treatment.

not germinate easily. It should be sown thicker than either of these. It should only have a very thin covering of earth, as the seed does not germinate if deeply covered. Fine earth should be passed through a sieve equally all over, and it should not be raked, but merely smoothed down with the back of the spade, or lightly rolled.

Horse-Chestnut, Sweet-Chestnut, and Walnut are sown like Oak, except that their covering of earth may be a little deeper.[1]

Maple and Sycamore are also sown on the surface of the ground in rows 10 to 12 in. apart, and one seed to 3 in.; but the covering of earth should only be $\frac{1}{2}$ to $\frac{3}{4}$ of an inch.

Holly.—After being mixed with sand and rotted in a heap for fifteen or sixteen months, the seed should be sown during March on beds smoothed with the back of the spade, and evenly covered with about half an inch of moderately fine earth. A light roller may then be passed over the bed to prevent too sudden drying of the surface. As the Holly-seeds are mixed with sand and cannot well be separated, in estimating the quantity of seed an allowance must be made for sand. The seed is apt to lie over—*i.e.*, seldom all germinates in one year; but the seedlings continue to come up for two successive years.[2]

Hawthorn is dealt with in a similar way to Holly.

Conifers.—Pine, Spruce, and Fir seed should only be sown in dry weather, otherwise particles of wet earth may cake round the seed and interfere with its germination. Sowing should therefore, if possible, only be undertaken after some days of dry weather, when the rake can be used freely without earth adhering to it.

Seeds of rare exotics should be sown in small flower-pots, and specially protected. If they grow too large for the pot, they can easily be transplanted into a larger-sized pot until big enough to plant out. This reduces the disturbance in planting to its absolute minimum.

(2) **Transplanting of Seedlings into Nursery-lines.**—Unless the *seedlings* are removed from the seed-beds for planting elsewhere, they become *transplants* by being pricked out in other beds (*nursery-lines*), and are there schooled (often by retransplanting) till they attain the desired size for planting in the open. Thus "1-year-1 plants" are two-year-old plants that have been transplanted as one-year-old seedlings and allowed to stand one year in the nursery-lines, while "1-year-2, twice transplanted," are three-year-old plants transplanted first as one-year-old seedlings and then again transplanted into another bed after standing one year in the first nursery-line.

On being raised from the seed-beds, the seedlings should be taken to a shed or shady place and sorted before being bedded according to size. If all mixed up higgeldy-piggeldy, the beds not only look untidy, but the plants do not thrive so well. And the stronger seedlings may often be sent out a year in advance of the others, if required.

Transplanting, of course, gives each individual seedling a larger growing-space and better conditions for developing its roots and foliage than it has in

[1] Unless Horse-Chestnut seeds be sown with the smooth side upwards and the scar below, the seedlings are apt to be weakly, and to have deformed roots. But Sweet-Chestnut should be sown with the point of the nut downwards.

[2] Later on, transplanting of Holly-seedlings into the nursery-lines and planting out should either take place in wet weather or else the ground should be well watered, as they are apt to suffer from drought.

Fig. 33.

a *b* *c* *d*

a *b* *c* *d*

Root-forming Effect of Transplanting in the Nursery.

a. Scots Pine,	2-year-seedling,	*not transplanted.*
b. Do.	do.	*transplanted.*
c. Pedunculate Oak,	do.	*not transplanted.*
d. Do.	do.	*transplanted.*

the more crowded seed-bed. It always entails expense in pricking out the seedlings in the nursery-lines, and means extra cost in the shape of requiring about nine times as large an area as the seed-beds and a corresponding outlay for weeding and tending. But the extra cost is amply repaid in the stronger, healthier, and more vigorous plants produced ; and transplanting is therefore the rule, except in the case of light sandy soil where two-year-old Conifer seedlings can be notched to form a satisfactory crop. It is only under very exceptional circumstances, however, that plantations are so free from weeds as to enable this to be done. And many plants which would be unlikely to thrive in the open, but which are still too good to cast on the waste-heap, can thus be improved to form fairly useful planting material. Thus, for example, in the case of two-year-old Conifer seedlings for notching, there will be many seedlings found in the seed-beds not good enough for sending out, but still quite good enough to be worth transplanting for a year into nursery-lines. The beneficial effect of transplanting, both as regards the root-system and the branchlets and foliage, can easily be seen if two-year-old seedlings of various kinds of trees be compared with 1-year-1 transplants of the same age. The difference will perhaps be most marked in Spruce, which should always be transplanted owing to the weak rootlets formed by the seedlings (Fig. 33).

Age for Transplanting.—It is usual to transplant seedlings when one year old, because two-year-olds have fewer and weaker roots in comparison with their size, and therefore do not establish themselves so easily. If plants are wanted at three (or four) years of age, it is far better to transplant them when one year old and leave them in the nursery-lines for two (or three) years, than to transplant them as two-year-old seedlings and keep them only one year (or two) in the lines, because one year is too short a time for the full advantage of transplanting to be obtained. When transplants left for over a year stand too close in the lines, this can easily be remedied by lifting and again transplanting each alternate plant.

Cases may, however, easily occur when transplanting can well be delayed till there is a large stock of two-year-old seedlings. Such a case has already been indicated. Supposing two-year-old Scots Pine and Larch seedlings are wanted for notching on a light sandy soil, then there is certain to be a large proportion of the seedlings not good enough to send out of the nursery, though otherwise healthy and far too useful to throw on the waste-heap along with the poorer weaklings ; and that intermediate class can with profit be put at about 4 × 3 in. in nursery-lines for one year.

When Oak and other trees are wanted of about 8 to 10 ft. high for ornamental planting, they should be transplanted every two or three years till they are of the required size.

Time of Transplanting.—The pricking out of seedlings can, of course, take place either in autumn or spring; and very often the point is practically settled by the way in which this special work fits in with other operations. All bedding and transplanting should be completed by May at latest.

In nurseries that are already in full working order, the transplanting of deciduous seedlings into the nursery-lines can take place any time after their shoots have ripened in autumn, while the transplanting of Conifers should take place in spring. Bedding operations should never be performed in frosty weather, as the tender root-fibres are then easily injured.

Least disturbance in the organism is occasioned in spring, when the plant has imbibed a comparatively large supply of moisture, and the time has arrived for the "flow of sap" to commence; hence that is *theoretically* the most favourable time for transplanting.

The transplanting of small seedlings should be undertaken while the weather is open and mild, or even wet, as the tender fibres are easily injured by sharp drying wind; otherwise, in dry weather, it is advisable to give them a good watering as soon as pricked out. But in this respect there is less danger in spring than in winter. It sometimes happens that, when there is a large area to plant, and the autumn season happens to be generally unfavourable, all hands are employed when the weather is suitable for planting; and nursery work must of course be postponed for a time, perhaps not being resumed until spring, after all the planting is completed.

Owing to their slender rootlets, one-year seedlings should not be transplanted till the spring season is sufficiently advanced to diminish risk of their being killed by cold, or of frost lifting the soil so that the plants hang over when the earth sinks again in thawing. *A good general rule* is to transplant all large plants in autumn and early winter, two-year-old seedlings (if necessary) during the second half of February, one-year-old broad-leaved seedlings during March, and one-year-old Conifer seedlings during April or early in May.

The Distance between Plants in the nursery-lines depends (1) on the size and age of the seedlings—whether strong or weakly, one- or two-year-old; (2) on the kind of tree, and its rate of growth during the first two to four years; (3) on the height of plant required (*i.e.*, the length of time it is intended to be kept there); and (4) on whether or not it is intended to go to the extra expense of *twice transplanting.*

In this last case, it is sufficient if the one-year-old seedlings have an individual growing-space of 6 sq. in. ($\frac{1}{24}$ of a sq. ft.) for conifers and 9 sq. in. ($\frac{1}{16}$ of a sq. ft.) for broad-leaved seedlings, which means a distance of 3×2 and 3×3 in. respectively—or $4 \times 1\frac{1}{2}$ and $6 \times 1\frac{1}{2}$ for more convenient weeding. Otherwise, if the seedlings are intended to remain in the lines for two or three years, a distance varying from 6×4 to 8×6 in., giving an individual growing-space of 24 to 48 sq. in. ($\frac{1}{6}$ to $\frac{1}{3}$ of a sq. ft.), is ample so far as the physiological requirements of the plants and convenience in weeding and tending are concerned.

The rectangular individual growing-space given by forming lines in which the plants stand at a different distance than there is from line to line, is adopted purely for convenience in weeding; otherwise, planting in squares (3×3, 4×4, &c.) would be preferable.

An unnecessarily great distance from plant to plant does not benefit the plants, although it entails greater expense through the extra land required. In the above cases there will respectively be twenty-four, sixteen, six, and three transplants per square foot of nursery-bed, and the total extent of bedding area required (usually about nine times the area of the seed-beds) can easily be calculated when the number of each class of plants has been fixed from the stock of seedlings available from transplanting. If specially large plants be wanted for ornamental planting, it is best to transplant them twice or thrice, increasing the distance according to the size of the young tree.

The distances recommended by Brown (in *The Forester*) were as follows :—

Kind of tree.	Age of seedling.	Distance apart		Individual growing-space is therefore :—	
		between rows.	between plants in rows.		
	years.	inches.	inches.	sq. inches.	sq. feet.
Larch	1	16	2½	40	0·27
	2	18	3	54	0·37
Scots Pine	1 and 2	14	2	28	0·19
Spruce, Silver Fir	1 and 2	10-12	3-4	30-48	0·20-0·3̇3
Ash	1 and 2	15	4	60	0·41
Oak and most other hardwoods	1 and 2	24	4	96	0·6̇6
Horse-Chestnut	1 and 2	16-18	6	96-108	0·6̇6-0·75
Hollies and Hawthorns	1 and 2	10-12	4	40-48	0·27-0·3̇3
Osiers	slips from 1-year shoots	15	3	45	0·31

The average distance in transplanting throughout Germany is as follows :—

Kind of tree.	Height of plants wanted.	Distance		Individual growing-space is therefore :—	
		between rows.	between plants.		
	inches.	inches.	inches.	sq. inches.	sq. feet.
Conifers (except Larch)	8-12	6-8	4-6	24-48	0·1̇6-0·3̇3
Broad-leaved trees and Larch	8-12	8-10	6-8	48-80	0·3̇3-0·5̇5
Do.	32-40	14-16	8-10	112-160	0·79-1·11
For special planting—					
Broad-leaved trees	6½ feet.	20	20	400	2·77
Do.	10 "	28-32	28-32	784-1024	5·44-7·11

Methods of Pricking-out.—It is more convenient for weeding if the transplant-lines run lengthways along the beds. One of the simplest and best ways of pricking-out is to stretch the garden-line along the bed at 3 or 4 in. from the edge, and open out a narrow trench with a long, narrow, sharp spade. The spade must be inserted vertically, so that the trench may have a perpendicular side about 8 or 9 in. deep, according to the size of the seedling (more for large plants, if being retransplanted), the earth taken out being placed immediately along the outer edge of the trench. The seedlings are then taken, plant by plant, with the forefinger and thumb of the left hand and placed in position at the required number of inches apart against the perpendicular side; and while the plant is thus held in position with the left hand, the loose earth is drawn in with the right hand and made as intimate as possible with the rootlets by gentle pressure. Care should of course be taken that the roots hang straight down in their natural position, and are not crinkled or bent; and care in this respect is far more profitable than hurrying over the job, to put in as big a day's work as possible.[1] When the whole row has been pricked out with seedlings, the garden-line is moved on the requisite 6 or 8 in. and the next furrow opened out, and so on till the whole bed is filled with rows parallel to each other and to the outer edges of the bed.

There should be no trimming of the seedlings with the pruning-shears, unless to cut off damaged parts. *Care should be taken not to plant the seedlings too deep*, as any alteration in the former relation of their roots to the ground-level (and therefore to moisture, oxygen, &c.) is always more or less injurious to any kind of plant, though, of course, different kinds have different accommodative power in this respect (Spruce least of all: see Fig. 58, p. 396).

An excellent mechanical aid, which works rapidly and renders it impossible for the seedlings to be set too deep, is Cardot's *notched seedling-pricker* (described by Boppe & Jolyet, *op. cit.*, p. 387). It consists (Fig. 34, p. 380) of a piece of wood, *a*, about 4 ft. long, notched at every inch (or inch and a half) to hold seedlings, which are kept in their place by another (movable) piece of wood, *b*. The seedlings are inserted into the notches at the required distance (3, 4, 6 in.) in such way that only the roots appear below, *i.e.*, the part under ground-level in the seed-bed; and when the perpendicular-sided trench has been opened out, the instrument charged with seedlings is laid along the edge of the trench with the rootlets close against the side, and the loose earth is filled into the trench again, when the upper piece of wood is first removed and the notched lower piece then withdrawn towards the planter. It is, of course, easy to make the instrument of different sizes and with notched spaces at various intervals to suit the work in hand with different kinds of plants.[1] As this instrument is 4 ft. long, it can be used for planting rows across the beds, instead of longways.—The British method in use twenty or thirty years ago was thus described by Brown (*The Forester*, here abbreviated):—

When a smooth edge has been made along the bed at 24 in. (for Oak) from the edge, and a spit of earth has been taken out along it to the depth of about 5 or 6 in., it is prepared for the first row of plants, by being made as nearly perpendicular as possible; for if sloping, the plants could not be easily set upright against it. Only just as many should be brought at one time as will serve for three or four rows. They should be laid evenly flat on the ground and a little earth spread over the roots to keep them cool and fresh; for the more carefully they are thus dealt with, the more likely are they to establish themselves well. . . . Each planter being supplied with plants, they should be regularly distributed along the edge of the trench in small quantities (say in tens) and at regular distance for more convenient handling. When the plants are all laid out, the planter takes his position on the left-hand side of the row he is to plant, and kneels down on his left knee, with his left side towards the newly cut edging. He then takes a plant with forefinger and thumb of his left hand, holding it about 1 in. above the root; and this part of the stem he places exactly where the line rested when the spit of earth was opened, inserting the roots of the plants at the left-hand side, and drawing in with his right hand sufficient good loose earth to cover the roots and keep the plant in place. The earth should be laid carefully on the roots, and given a slight pressure with the right hand to prevent

[1] This particular part of the work can be better performed by women and children than by men.

its getting detached from the perpendicular side and allowing the plant to fall from its place. And so on all along the line, the young plants being inserted 4 in. apart (24 × 4 in.) When the plants are in their places a little more of the finest earth should be added with the spade to that already laid on the roots with the hand, but only enough to cover the roots with about 3 in. of soil, after which *the whole line of plants should have the loose earth gently firmed over the roots by a slight pressure with the foot.*[1]

In Germany, the chief kinds of trees are thus treated in the nursery (compiled from Lorey, *op. cit.*, pp. 486 and 488) :—

Kind of tree.	Seedlings are raised	Transplanted into nursery-lines at age of	Used for planting at	Remarks.
		Years.		
OAK . . .	in seed-beds	1-2	3-4 years	4-6 ft. plants are again transplanted, and are put out at 6 years of age.
BEECH . .	under protection of old trees, or are taken from the woods	...	2-year-old (seedlings)	For plantations or underplanting.
CHESTNUT; WALNUT	in seed-beds	...	1-2 year (seedlings)	...
ASH; MAPLE and SYCAMORE; ALDER *	do.	1-2	3-4 years	For coppices only the roots of Maple, Sycamore, and Alder need be planted, the stem being removed by the clean cut of a hatchet.
ELM . . .	thick sowing on a lightly rolled seed-bed, slight earth-covering, and then again light rolling	...	all sizes from 1-year-old seedlings upwards	...
ACACIA . .	in seed-bed, very thinly sown	...	2 years (seedlings)	...
LARCH; AUSTRIAN, CORSICAN, and WEYMOUTH PINE	in seed-beds	1-2	3-4 years	...
SCOTS PINE .	do.	1-2	1-2-year old (seedlings), or 3 years (transplants)	...
SPRUCE . .	in seed-beds, or from the woods	1-2	3-4 years	
SILVER FIR .	taken from the woods	2-3	5-year-old	...

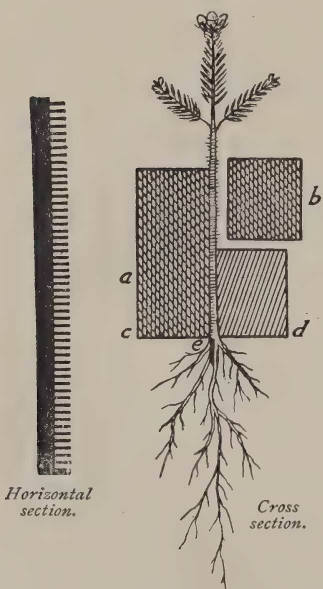
* *Alder* seed-beds should be kept moist in spring by watering or covering them with damp moss. The seed should be sown broadcast, and only slightly mixed with earth (*not* covered). As *Ash*, *Maple*, and *Sycamore* have opposite leaves, they are apt to form double leaders, and this should be checked when noticed.

Transplants of all kinds should usually be left two to three years in the nursery-lines, as one year is too short a time for getting the full advantage of this measure.

[1] This *treading in* of young seedlings on the transplant-lines is just as pernicious a practice as planting in the open by means of *notching* may often be on any but very light sandy soil. (See remarks on p. 389.)

(3) **Tending the Nursery.**[1]—(*a*) *Seed-beds.* Protection can be given against *heat, cold,* and *heavy rain* by covering the seed-beds with leaves, moss, or straw, which must be removed when germination is about to take place, or by sticking in branches of Spruce, Fir, or Pine (with healthy foliage only), or by placing light open-work hurdles on supports at about 3 ft. above the bed. *Drought* may necessitate watering. Against *drying-winds* upright hurdles form the only artificial protection, unless hedges can be grown on the windward side.

Fig. 34.



Cardot's Notched Seedling-pricker.

a. The main piece of wood notched to contain the seedlings.
b. The movable piece of wood to hold the seedlings in position.
c e d is placed on the ground-level, the point *e* being at the lip of the perpendicular side of the trench.

Birds[2] can best be kept off by wide-meshed wire-net frames, by automatic scare-crows in which the wind is made to work a wooden bell and clapper, by hanging numerous little pieces of looking-glass by threads from a string extending from end to end of the bed at some height above the ground, by hanging old fishing-nets on posts over the beds at a height of 12 to 18 in. above the ground, or by firing a gun or pistol to frighten them away. Jays and pigeons should be shot.

Mice[2] can only be got rid of by laying poison in drain tiles. *Squirrels* should be shot, and *moles* trapped. *Rabbits* can now only be kept out by a 4-ft. wire-net, bent well outwards at top and also for at least 6 in. at the bottom (under the ground), the lower half of which consists of 1 in. mesh, or at most $1\frac{1}{4}$ in. Such a fence also keeps out *hares.* Against *roe-deer*, however, a strand of barbed wire is necessary in addition, a foot above such a wire-fence.

Against *injurious insects,* the best protection is to hang up good nesting-cases for starlings and other insectivorous birds.

Cockchafers.—Grubs in light soil, and *wireworms*, specially destructive in Oak seed-beds, are two of the worst insect-pests in nurseries. They can only be got rid of by digging them up when they are found to be doing damage; but the spraying of benzine over the soil to the extent of about 3 gallons per acre is said to be very efficacious (Boppe et Jolyet, *op. cit.*, p. 363). *Mole-crickets* are also very destructive, and must be regularly hunted by destroying their eggs when found in the nests in May and June; by sinking large flower-pots (with the

[1] More specific details than are here given will be found in vol. ii., Part IV., *Protection of Woodlands.*

[2] If, before sowing, the seed be slightly moistened and strewn over with red-lead powder, then well stirred about so that each seed becomes covered with a coating of red-lead, this will ensure protection against its being devoured by birds and mice.

bottom hole plugged up) into the ground where a run has been formed; by forming large heaps of horse-dung (about 40 to 60 cubic ft.) in September in an infected part of the nursery, and breaking it up again in December or January, when many mole-crickets will be found in a torpid condition; or by pouring petroleum into holes leading to the underground galleries they make, and then killing them when the petroleum drives them to the surface. If *slugs* are bad, traps consisting of pieces of wood greased with rancid butter can be laid greasy side downwards in the beds attacked. Early in the morning the slugs should be collected.

(*b*) *Transplant-lines.*—After the seedlings have come up, *watering* may be necessary during very dry periods. Loosening the soil between the drills helps to keep the earth below cool and moist, though the loosened particles afterwards get thoroughly dried out; but this is only effective when the soil has some time before been moistened by a soaking rain. *Weeding* is necessary several times a-year; and loosening the soil in between the rows is useful. Where seedlings suffer from *overcrowding*, they should be thinned by clipping with small shears (*not* by pulling out). The *weeding of the seed-beds* should be done in damp and cloudy weather, as then there is less likelihood of the soil coming away with their roots, but *weeding of the transplant-lines* is carried out with the hoe in dry weather before the weeds grow to any considerable size; for if the operation be left till the weeds are strong, the work becomes more costly, as well as more difficult to perform. In winter the plants can best be protected from *frost* by spreading leaves, sawdust, or dry peat-fibre over the beds. And the plants themselves may be improved by the careful removal of *double-leaders.*

Few long-established nurseries escape infection with *fungous diseases* to a greater or less extent; and in the former case it may even be necessary to remove the nursery to some other place. If the reddish-brown spots caused by *Leptostroma* (*Hysterium*) *pinastri* appear on Pine foliage during late summer or autumn, the infected plants should be removed and burned, and the beds used for other kinds of plants. Any seedlings showing the scorched appearance arising from *Phytophthora fagi* should also be at once removed and burned, because this disease spreads rapidly. Against both of these fungi a watering (of the foliage in the former case, and of the seed-bed in the latter) with a solution of $4\frac{1}{2}$ lb. of bluestone (copper vitrol) and 1 quart of ammonia in 50 gallons of water is said to be of assistance in preventing the spread of the disease. When one- to three-year-old Oak plants get attacked by *Rosellina quercina*, the plants should also be removed and burned, and the infected parts should be isolated by a 12 to 15 in. deep trench all round, to prevent the spread of the fungus through the soil.

8. **Lifting Plants** for transplanting, or for removal from nursery, should be done in such a manner as to disturb as little as possible the root-system and the small clods of earth adhering to the roots and rootlets. The disturbance is of course greatest in naked plants when the matrix of loose friable earth falls away from the roots and leaves them comparatively bare; and it is least if the plants are raised with *balls of earth* around their roots, when the whole or most of the mother-earth is transported along with the plants. But the cost of this operation increases rapidly with the size of the plants.

Neither seedlings nor small transplants should ever be pulled up by hand, even out of loose soil. One of the simplest and best methods of lifting seedlings or transplants consists in taking out, with a sharp long spade, a narrow but deep spit of earth, deep enough to reach below the roots of the plants, and then detaching the latter by means of slight pressure applied on the other side of them with the spade or with a three-pronged fork or hoe. One- and two-year-old Conifer seedlings and transplants so treated retain all the soil round their roots even on light land, so that there is no need of trimming damaged rootlets.

Large plants, and those that have deep tap-roots, are of course the most difficult to lift, and even when the spit of earth is taken out clean and deep, they seldom come away quite whole, so that one is forced to trim the damaged part with the pruning-shears or pruning-knife. But no pruning of healthy rootlets should take place, because these stronger tougher parts are just those of greatest value in helping the plant to establish itself when replanted. Such plants should be lifted with balls of earth, as this affords them the best chance of thriving. If the plants are very large, they can be prepared for this a year before removal, by sinking a long, thin, sharp spade down to its full depth at a suitable distance all round the four sides of the plant, thus cutting through the outer rootlets and inducing it to form fresh rootlets within the clod. Or a similar operation may also be done with a cylindrical nursery spade (Fig. 35). Very large transplants can best be raised by two men using heavy grubbing-irons (Fig. 57, p. 396).

Fig. 35.

Heyer's Cylindrical Spade for lifting transplants and for planting work.

Fig. 36.

Semicircular Nursery Spade for lifting transplants.

In Germany, the lifting of transplants, as also the preparation of plants for lifting, is usually done by means of cylindrical, semicircular, or conical spades. In the former case the balls of earth fit in exactly into similar holes made with a like instrument of the same size. Thus the disturbance is minimised, and there is much less danger of the plants being moved by wind before they succeed in establishing themselves firmly in their new home.

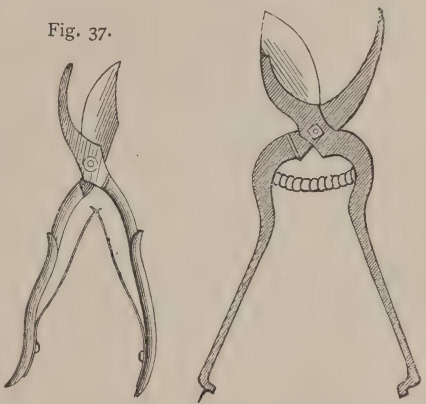
There are many such instruments in use (Figs. 35, 36), but in general utility none of them surpasses **Heyer's cylindrical spade.**

This little instrument is worthy of introduction into Britain. It is from 30 to 38 inches in height; the handle of wood is fastened by iron bands to the wooden stalk, the lower part is of iron. The lower diameter of the cylindrical sheath varies from $1\frac{1}{2}$ to 5 in., but 3 may be taken as the average; the upper diameter is a few lines more, and the height is usually equal to the diameter. The stem of the young plant being allowed to pass through the opening *c a*, so as to come in the middle of the circle, the instrument is forced into the soil up to *d*, where a small iron plate prevents its further progress. One side, c e, is sharpened, the other remaining blunt, so that there is little danger of the workman cutting his fingers in getting out the ball of earth. The whole is turned by means of the handle, and then drawn out, plant and earth remaining in the cylinder owing to friction. By placing the hand across b d, inverting the instrument, and, if requisite, applying a slight pressure from above with the thumb, the cylinder of earth falls gently into the hand. The holes into which the plants are to be brought are prepared with similar instruments of the same dimensions, and are thus rather larger than the balls of earth ; but both having been slightly compressed during the operation, the first shower of rain (after planting out) corrects this. On inserting the balls, the workman (or boy) presses them down firmly with his thumbs, so as to facilitate their adhesion to the surrounding soil. A lad or a woman can with a circular spade of 2 in. diameter plant 700 or 800 seedlings per diem, including carrying them a short distance from the nursery. For dry loose sand, or for very wet soil, this instrument is not intended ; such soil is not cohesive enough to form the balls of earth. (*Trans. High. and Agri. Socy. Scot.*, 1876, p. 234.)

9. **Pruning of Nursery Plants.**—When the transplants are lifted for sending out of the nursery, *pruning* of the branchlets and twigs is sometimes necessary to maintain a proper balance between the more or less disturbed and damaged rootlets, and the organs of transpiration and assimilation (the foliage). When the damage to the root-system is considerable, as in the case of large plants, the deciduous species (*i.e.*, all broad-leaved trees and Larch, the kinds which lay up the largest stores of reserve nutrients) can stand a fair amount of pruning (best of all Oak and Elm, which can be trimmed in the nursery-lines to improve the shape of the stem, though even with the Oak all *unnecessary* pruning should be avoided), but evergreen Conifers should be trimmed just as little as is necessary to try and maintain the balance between roots and foliage.

Fig. 38.

Fig. 37.



Pruning or Trimming Shears.

Pruning should always be done with a sharp pruning-knife or the pruning-shears (Figs. 37, 38), the former being preferable for removing any large twig, as it is then easier to give a good, clean, sloping cut.

The greater the general recuperative power of the different kinds of plants (see p. 332), the better they stand pruning and trimming.

If only roots are to be sent out for coppices or for underplanting, it is best to lay the plants on a block of wood and decapitate them with a hatchet as soon as lifted.

When large transplants are lifted from the nursery for planting, the **larger branches** often need shortening. This ought to be done so as to leave only about one-half of their whole length remaining, with, if possible, a few small twigs on each, to elaborate the sap in spring. This trimming will give the young stems a pyramidal form (Fig. 40). When there is a double leader the side-shoot should be pruned. When the leading-shoot gets damaged or weakly from any cause, it may sometimes be necessary to train up a side-shoot to take its place; and this is done by the removal of the leader, and tying up the side-shoot, as shown in Fig. 41. Again, where flexures or bends in the stem occur, they may be remedied by pruning, as shown in Fig. 42, which exhibits a young Oak under treatment.

Fig. 39.

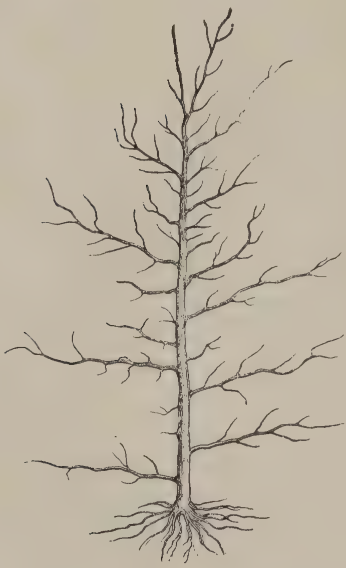


Fig. 40.

A large young Oak trimmed for planting.

Natural growth. Pruned condition.

10. **Package and Transport of Plants.**—Seedlings can easily be moved to the nursery-lines in baskets or on hand-barrows; but when either seedlings or transplants have to be sent to some distance, greater precautions have to be taken against heat, cold, and drought. To prevent the drying up of young naked plants, the roots should, immediately on being lifted from the beds, be tied with coarse twine in bunches of fifty, and packed carefully in damp moss, to form separate bundles of convenient size. To prevent heating of the foliage, evergreen conifers should be packed with the leaves of one lot touching the roots of another. This is much better than *mulching* or dipping them in liquid loam, which ultimately tends to cake round the roots and throw them into an abnormal condition. In very dry weather the moss should be moistened from time to time if the distance is great. If the distance from the nursery to the site of the intended plantation is considerable, the plants have to be taken by cart, a covered cart being best, as it protects the plants from sun and wind. If the general method of planting is with balls of earth,

Fig. 41.

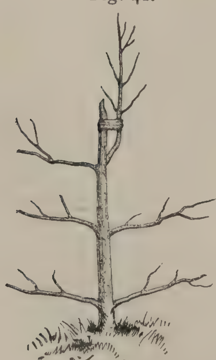


Fig. 42.

it will pay to have a light, but specially deep, covered car, like a baker's van, fitted with trays to hold the plants.

It is astonishing how large a number of plants raised with Heyer's cylindrical spade can be despatched at once in such a cart, if thought and care be given to a suitable arrangement of trays.

In Germany the cost of raising plants and packing them for transport is reckoned to be on the average as follows (*Forst- und Jagd-Kalender*):—

1. Lifting 10,000 one-year-old seedlings . . .	0·2—0·3	of one day's work for a man.
2. Lifting 100 ordinary-size transplants with common spade, nursery spade, or cylindrical spade . .	0·2—0·4	
3. Lifting 100 extra-large transplants (3 to 6 ft. high) with heavy grubbing-iron	0·8—1·2	
4. Packing one-year-old Scots Pine seedlings in moss in bundles of about 30,000, sewing coarse matting round them, and tying them up ready for despatch by railway, per 1000	4 pence.	
5. Packing transplants (20 in. to 5 ft. high) in straw, and preparing them for despatch by railway, per 1000	7 pence.	

11. **Storage of Plants.**—From a home-nursery, of course, only so many plants will be sent to the plantation day by day as the planters can manipulate. But if plants received in bulk from a great distance by railway cannot be planted at once on arrival at the planting ground, they should as soon as possible be unpacked, and if necessary the roots should be moistened, and the plants then *sheughed* or *heeled in* by being bedded temporarily in shallow trenches opened, if practicable, in light soil and in a fresh, cool, shady spot near where they are wanted for planting. It is self-evident that the less the roots are exposed, and the sooner planting takes place, the easier it is for the plants to overcome the disturbance caused by removal, and the fewer the number likely to damp off if the following summer prove hot and dry.

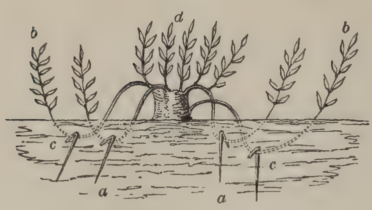
Layers and Slips.—Besides growing them from seed, plants can also be obtained artificially from *layers* or *plashers*, or from *slips* or *cuttings*, as well as naturally by detaching *root-suckers* from their parent trees in the woods.

Layering or **Plashing**[1] consists in having a piece of ground first of all planted, at about 6 ft. apart, with Elm, Lime, or any other tree that it is desired to propagate. Thin coppices and underwoods can thus be improved by plashing Ash, Sweet-Chestnut, Oak, and any other available kinds on the ground. After standing three or four years, they are cut over a little above the ground, like osiers. When the buds left above ground have flushed their shoots, these are in autumn "layered" or partially buried about 4 in. deep in the ground (Fig. 43), after this has been dug and cleared of weeds and stones. The shoots are pegged down (*a a*) to keep them firm, while the upper end of each (*b b*) extends above ground and forms the new stem, the new root-system becoming developed on the buried portion (*c c*) in the course of the following spring and summer. Each shoot then becomes an independent self-sustaining individual, and can be detached from the parent plant either for transplanting into the nursery or for putting out into the open. In

[1] See also chap. v. p. 460 for old English method of *plashing* in the copse-woods.

removing these self-rooted young plants from the parent stem, care should be taken to sever their connection with a sharp knife before raising with the spade the clod containing the new root-system. When all the young plants have been removed, the stumps of the severed branches should be cut off, when fresh stool-shoots will be flushed (*d*), which can afterwards be layered.

Fig. 43.



Method of Layering.

a a. Wooden pegs keeping layers in the ground.
b b. The growing points of the layered shoots.
c c. Place where roots are formed.
d. Aftergrowth of fresh shoots for layering.

This process may go on continuously, each summer's shoots being in autumn layered to form new plants; and while these are in the act of rooting, the parent stool is again busy in reproducing new shoots to succeed them. When a severe drought sets in, the ground should be well watered.

The efficacy of layering in coppices and underwoods is usually increased if the shoot plashed be given a few slight cuts near the joints on the lower side, or if (especially in the case of Lime) it be given a good firm twist with the hand before being layered into the ground. Either of these measures no doubt causes sufficient disturbance to call forth a strong natural effort at recuperation and reproduction.

The Dutch Method of Layering is slightly different, for plants of 5 or 6 ft. high are put out in autumn, at distances of 8 to 12 ft. apart, in light, well-prepared, manured soil, and then cut off close above the ground. As soon as the new shoots have shed their foliage in the following autumn, they are carefully bent down or layered in trenches of about 1 ft. deep, that are lined with good mould before the earth is filled in again and trodden down. The tips of the shoots come for about 2 to 12 in. (according to circumstances) out of the soil, and are assisted in attaining an upright development by having tufts of turf laid below them. If these main-shoots should have side-shoots, they can also be layered at the same time; but any shoots in excess of those that can be conveniently layered are cut away. In the following autumn—that is to say, after being layered for one year—the young plants are separated from the parent stool. Not much stress is laid on the retention of numerous rootlets, for the new plant is cut through in such manner that the rooted end forms the straight continuation of the stem; and it is only when the root-development has been poor that part of the crook is included along with the detached layer. The stem of the new individual plant is then severed with a slanting cut made about 4 to 6 in. above the rooted portion, which is next put out in rows on prepared manured land trenched to a depth of 16 to 20 in.; the rows are usually 2 ft. apart, and in these the plants stand about 15 in. distant. No further transplanting is necessary; but in the following autumn they are cut back again close to the ground, and during the next spring only the best of the shoots is left to develop. In the course of the next five or six years this develops into a stout young stem, ready for planting wherever required. The only tending consists of keeping the beds free from weeds, though sometimes the lower shoots are cut away in order to allow the workmen to move about more freely during the weeding operations. Such Dutch Elms, nearly all of the species *U. campestris,* are characterised by straight and rapid growth, smooth bark, and good deep root-system. As they increase in age, the parent stools produce more numerous and better shoots than at first. When they become too high to permit of the shoots being layered easily, they are simply sawn through close to the ground—care being, however, taken to smooth off the ragged surface with an adze or similar instrument (Burckhardt, *Säen und Pflanzen*, p. 200).

Slips, Sets, or Cuttings form the usual method of reproducing Willows and Poplars, although other softwoods can also be easily multiplied in this simple way. It consists in making cuttings from the stool-shoots, stems, or branches of a growing plant (tree or shrub). Usually, for Willows the cuttings are smaller than for Poplars; while for Osiers they are of course smallest of all. In either case the sets, on taking root, grow much quicker than seedling-plants. The main points of this method are to make a clean slanting cut at the lower end, and to insert this deeply into prepared ground (beds, strips, or holes), the holes, if deep, being made with a pointed iron rod or a steel-tipped wooden stick of the size of the slips, unless the soil is naturally very light and porous, and the slips cut be set close at slight expense. The quicker the planting can take place after cutting, the more successful is the result likely to be. The drier the soil, the deeper the slip should be planted; and if small slips are put slantingly into the ground, they generally do better than if set upright. The best time for planting slips is in spring, when the buds have swollen and are near their breaking into leaf.

Slips for tree-willows may be cut slantingly at both ends in lengths of $2\frac{1}{2}$ to $3\frac{1}{2}$ ft. from three-year-old branches. The side-twigs are cut away, care being taken not to damage the bark; and the lower end is trimmed with the pruning-knife, if necessary, to procure a clean sloping surface, when the slip is inserted for about two-thirds of its length into the prepared soil, so that only three or four buds remain above ground.

Osier cuttings should be taken about 12 in. long from the strongest of the one-year-old shoots, and transplanted into nursery-lines at about 12—15 by $2\frac{1}{2}$—3 in., the cuttings being inserted for about two-thirds of their length into the soil. They should be cut with a long slant at the upper end to give as little room for rain lodging as possible. Such transplants throw out strong fibrous roots during the summer, and are fit for putting out in the following spring.

Poplar sets are usually 5 to 6 ft. long, and vary up to about 2 in. in diameter. They should never be forced violently into the holes made to receive them. Should these be too large, the vacant space round the set can easily be filled in with earth, and well firmed at the top to prevent the set being shaken by the wind.

The planting of sets is one of the cheapest ways of wooding damp places, such as along marshy ground near streams and hills.

Planting does not necessitate anything like so much soil-preparation as is usual for successful sowing—unless in such exceptional cases as moorpan or the intensive work of Osier-cultivation.

On very light porous soil (sandy), where naked seedlings can with advantage be notched, no soil-preparation at all is necessary; while under ordinary circumstances it is confined to the making of holes for pit-planting, or of small mounds in damp spots. Say these pits are 12 in. square and 4 ft. apart from centre to centre, that means only 2722 square ft. specially prepared per acre, or one-sixteenth of the whole area.

The preparation of continuous strips or bands, as in sowing, is unnecessary for planting if transplants of the usual size are used, and is even undesirable, as it induces cockchafers to lay their eggs there. For planting, therefore, soil-preparation is usually confined only to the opening of holes or pits of suitable size and depth for the plants intended to be put into them.

Planting may take place either (1) with transplants lifted from the nursery-lines with *balls of earth round the roots*, or (2) *with naked plants* (seedlings and small transplants).

1. **Plants with Balls of Earth.**—If the plants are lifted with the cylindrical or the conical nursery spade (see p. 382), so that the balls have a regular shape, they are simply inserted into *holes* prepared with a similar instrument of the same size,—a method which is, of course, only practicable when the nursery soil possesses a fair degree of stiffness. Otherwise, if the soil be light or the plants be lifted with spade or hoe so that the balls of earth have no very regular shape, *pits* for planting them in must be opened with spade, hoe, or pick and mattock, unless they are planted on mounds in damp spots.

2. **Naked Plants** may either be *notched* or *slitted* into light porous soil, or else planted in *pits* or *trenches*, or on *mounds* or *tumps.*

The Methods of Planting are therefore fourfold—(1) *Notching* or *Slit-planting*, (2) *Planting in deep narrow holes* (made with special implements), (3) *Pit-planting*, and (4) *Tumping* or *mound-planting.* Each of these methods is especially suitable for given kinds of soil, while the best method is in each case that which achieves success with the smallest outlay.

1. **Notching or Slit-planting**[1] is usually done with the common spade,

[1] This is how the British methods of transplanting and notching strike a Continental forester :—

"The planting material used, and the methods of planting adopted, quite shock a German forester. Apart from the few cases where, as already mentioned, natural regeneration is made use of, the establishment of woods is by planting, not by sowing. Artificial sowing is not possible, owing to the universally strong growth of grass or heather, and the damage done by rabbits. In planting, very large transplants (often four to six years old) are used, and all that Continental foresters demand in regard to root-form is held in high disdain. The transplanting of seedlings is effected in this way : a shallow trench, about a couple of inches deep, is formed ; into this the plants are laid closely together (about 2-2½ in. apart) in such a manner that their roots are bent quite to one side. The little trench is filled in with soil, firmed with the foot, and the operation is finished. The consequence of such treatment is, that instead of the roots taking a vertical direction, they grow at right angles to the stem, and the root-collar is buried too deeply. In schooling transplants, the same operation is repeated.

"These unnaturally crippled plants are admirably suited to 'notching'—the method by which Conifers are customarily planted in Britain. With a spade two incisions are made into the soil, either in the form of an L or a T. The corners of the sod are raised somewhat with the spade ; the plant, with its horizontally-lying roots, is slid into the opening, and the flap of sod is allowed to fall back. With a tread of the foot the young tree is considered as planted ! Certainly an easy and expeditious system !

"The results, of course, soon show themselves. In spite of otherwise favourable circumstances,—productive soil, absence of spring drought, and frequent rainfall,—a very considerable number of the plants miscarry. I saw an area in Peeblesshire, for instance, where 60 per cent of the plants were dead, and a further number had not developed their buds ; many more will obviously die in the ensuing year. Were we to employ such a method of planting upon light soil in Germany, probably not 5 per cent of the plants would remain alive." (Prof. Schwappach, in *Trans. Roy. Scot. Arbor. Socy.*, vol. xvii., part ii., 1904, p. 174.)

and is the practice generally followed in planting with small naked plants, such as all two-year-old seedlings and 1-year-1 transplants of Scots Pine or Larch. It consists in making an L- or T-shaped incision into the surface of the soil, opening this up from below by pressing down the handle of the spade, inserting the young plant into the opening at the angle, and then firming down the soil again with the foot.

It is self-evident that such a method can only be successful on a very light porous soil (sandy), and even then the roots are forced into a cramped unnatural position, differing greatly (Fig. 44) from the more or less vertical position they occupied in the seed-bed and the nursery-lines. Even in porous sandy soil, where the quartzy particles of earth offer least mechanical hindrance to the expansion of the rootlets, the roots show distinct traces of this unnatural treatment for very many years afterwards. And when this method is tried on stiffer loams and on clays, it is hardly rational to expect anything but failure in the plantations, because the roots soon get to look as if they had been dipped into a glue-pot before being put into the soil. It is similar to, but even worse than, the old practice of bedding transplants by laying them along trenches, throwing the soil on them, and then firming them in with the foot; because the nursery-beds were specially prepared and the seedlings small, whereas here the seedlings are larger, while the soil is poorer and in its rough natural condition. It is the cheapest of all methods of planting; but it can only be expected to succeed on very light soil, and is entirely unsuited to stiff loam or clay. The plants cannot soon start growing; and if the soil is inclined to grow weeds, the plants run the danger of being choked.

Fig. 44.

A man and a boy can, if smart at work, notch up to about 180 plants an hour (3 a minute), or about 1200 to 1300 in the course of a short late autumn or early spring day, and about 1300 to 1500 during the longer days in March and April. For notching at 3 by 3 ft. (4840 per acre) it may therefore be safely reckoned that each man and boy can do at least $\frac{1}{4}$ acre a-day, or $1\frac{1}{2}$ acre per week,—which is at least four times as quick as pit-planting can be done at 4 by 4 ft. (2722 per acre), even if the pits have been previously opened.

Notching was formerly, and still is, a very favourite system of planting in Scotland. The best form, *double-notching*, is thus described by Brown (*The Forester*, here abbreviated):—

Notching is done by a man and a boy. The man first makes two deep cuts (1 and 2) with his spade into the turf, crossing at right angles (Fig. 45), and then a third cut across the end of one of the former about 5 or 6 in. from the cross-cut centre, where the plant is to be put, *a*. When the third cut is made the handle or head of the spade is bent down nearly to the ground, so as to open the turf in the cross-cut centre; and the boy inserts the plant and draws it to the centre, the planter holding the spade down until the boy has the roots rightly adjusted after passing them through the cut. The operator then raises the handle of his spade and withdraws it, letting the earth and turf down upon the roots of the plant, and he then makes all the cuts close and compact about it by tramping with the forefoot first and then with the heel. If the cuts do not close tightly, when the sod is of a hard benty nature, a piece of thin turf may be taken from the open space and placed over the cut, in order to keep out the drought; and this also gets tramped in with the foot. When the area to be planted is on a sloping brae, the operator should stand with his back towards the hill. By doing so, the notches are made so as to collect and retain surface-water. In notching care should be taken not to insert the plants too deeply, for this is a frequent error, detrimental to the health of the plants. To avoid this, the boy should hold the young tree between his forefinger and thumb, just about 1 in. above where the earth has been formerly. When he puts it into the cut, he should hold it firmly by that part until the turf falls down into its place; and if he finds that the turf, when down, is much above the points of his finger and thumb, he must pull the plant up a little, so as to have these resting on the surface of the turf. The boys are frequently left to make the plants firm in their place; but this should never be allowed by any man who wishes to do anything like his duty to his employer. The forester must therefore see that the men employed in notching, and not the boys, are responsible for the planting being done in a proper manner.

Fig. 45.

Double-notching.
1. First cut.
2. Second cut.
3. Third cut.
a. Where plant is put.

2. **Planting in Deep Narrow Holes.**—For light descriptions of soil there are some **German methods** of planting very closely allied to notching in their principle. They are all based on the principle of making a deep narrow hole in the ground first of all, and then applying pressure to bring the soil in close connection with the roots. Hence they are (like notching) only suitable for light porous soil and not for binding land, as stiff loam or clay would be apt to flatten the root-system of the small naked plants, which are alone used in this way.

One of the best of these methods for ordinary purposes is planting with the *Planting-stick.* The principle and method will easily be seen from the accompanying illustration (see Fig. 46). The planting-stick may either be an iron instrument or simply a crooked bit of wood shod with iron at the tip, about 3 to 4 in. broad at the top, and 1 to 2 in. broad at the point. The first insertion (*a*) into the soil is vertical, to form the bed for the plant; the next, about 2 in. away from the first, is slanting, as in the figure (*b*), and takes place, with simultaneous pressure in the direction from *b* to *a* so as to fix the seedling, when the plant has already been brought into place. In order that the roots may lie properly, the plant is inserted deeply into the hole, shaken lightly, and then pulled up into its true natural position, to prevent the roots becoming knotted or twisted. A third pressure with the instrument (*c*) is made in order to close up the aperture at *b*. The whole work can be easily done by one man, woman, or child. This is an extremely cheap method; and it has the great advantage over notching, that it ensures the roots having a natural and more or less vertical position. But here, even in soft light soil, there is

Fig. 46.

The iron-pointed Planting-stick.

always the fact that the roots are pressed flat as a pancake, which is unnatural. And the stiffer the soil, the greater is this flattening process, and the less is the chance of the plant being able to recover from it and resume the normal form of root-system. The chief modifications of this method consist of planting (1) with a wedge-shaped wooden spade tipped with iron, which is used in the same way as above, and (2) with *von Buttlar's planting-iron*, somewhat like the planting-stick in shape, only much heavier and more pointed, which is *thrown* into the ground to make the hole in the first instance.

These methods of planting are very easy to learn. The chief points to be insisted on are (1) that the plant should be inserted well into the first opening, (2) that it must then be lightly shaken, and (3) afterwards drawn up to the required height, to avoid the bad effect of planting too deep.

3. **Pit-planting**, or planting in holes of about the same top-width as their depth, is the usual method of planting transplants of all kinds of trees. The holes or pits can be prepared either by specially-shaped spades or else with the common spade, the planting-hoe, or the planting-mattock.

As previously indicated, if the plants are lifted from the nursery-lines by the cylindrical or the semicircular spade (see p. 382), they can simply be inserted into similar holes made over the planting area with a like implement of the same size (Fig. 47). But if the holes have first of all to be opened out

Fig. 47.

Planting with Cylindrical or Semicircular Spades.

a, Transplant as lifted from nursery-bed; *b*, Hole made for its reception on area to be planted.

with the common spade or mattock, there is more manipulation required in settling the plant in its new and permanent abode. In the former case the holes can (and must, in fact, to avoid being filled up or losing shape) be made at time of planting; while in the latter they are best opened just before planting if the soil be light, dry, and porous; but if the soil be stiff and heavy, then they should, for spring planting, be made in autumn to let the soil get weathered by frost during the winter.

In opening up the pit, the turf, the fine earth, and that of poorer quality should all be placed separately.

The size of the holes to be made depends on the size of the plants (if naked) or of the balls of earth raised from the transplant lines. For the smaller sizes of transplants they can most cheaply be opened with the spiral spade (see Fig. 28, p. 359); but larger pits from 8 or 9 in. square and 9 or 10 in. deep, up to 12 to 15 in. square and about the same depth (according to the size and kind of plant), have to be made with hoe or spade, or broken up with the planting-mattock or pick on hard soil or wherever there are stones and old roots (Figs. 48, 49). The stiffer the soil, the larger and deeper the pits need to be; but for ordinary planting at about 4 × 4 ft. (2722 plants per acre), pits of 10 × 10 × 10 in. are usually quite large enough. Such work can generally be given out on contract, at prices ranging from about 1s. to 2s. 6d. per 100, according to the size of the pits and the nature of the soil.

Fig. 48.

The Planting-Mattock.

Fig. 49.

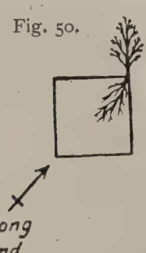
The Planting-Hoe.

Pit-planting is better done by a man and a boy than by a man alone. Indeed, for the manipulation of the plants after once the heavier work of opening the pits has been done, the deft fingers of women and children are better fitted than men's hands.

The plants should be carried in baskets, with the roots well protected by damp moss or fresh earth *to keep the root-hairs fresh and active, as this is one of the chief conditions for enabling the plants to establish themselves quickly.*[1] At each hole one plant[2] should be taken out of the basket (the others being kept carefully covered), and so held in the pit by the boy that the roots assume their natural vertical position, and do not stand lower below the ground-level than they did before. The finer earth is then brought into the bottom of the pit and compost earth put next the roots; and after that the pit is gradually filled with the coarser earth, the coarsest of all being crumbled between the fingers and coming on the top. As the pit is being gradually filled, pressure is applied with the hands, first gently, then becoming stronger as more earth is put in; and finally, when the sods of turf are replaced face downwards on the top, the whole is firmed with the soles of the feet.

[1] If the root-hairs get shrivelled up by direct contact with the air, as soon takes place if the air be dry and a strong breeze is blowing, then the suction-roots cannot possibly act till new root-hairs have been formed. And this means loss of time, and general disturbance in the organism.

Fig. 50.



[2] Brown (*The Forester*) recommended two plants being set at different corners of each pit on poor land and exposed situations. This does not seem advisable. If both should grow up, then they stand far too close to grow well. But supposing only one lives to grow up, it succeeds much better if standing in the middle of the pit. On very exposed parts it may perhaps be advisable to set the plant in that corner of the pit which is opposite to the prevailing wind, so that it may have the support of the solid ground (Fig. 50). Thus, if the strong winds come from S.W., the plant would be put in the N.E. corner of the pit, and so on. But unless there be such special reason, it is best planted in the middle of the pit.

If one man do the work alone, he has to place the plant against the wall of the hole, made vertical for this purpose, with his left hand, while he fills in the pit with earth, so that the plant has neither the full advantage of the soil-preparation on one side, nor a fair chance of the roots being placed quite in their natural position. It is therefore poor economy to spare the addition of the boy; and a man and a boy working together should plant a larger number of pits than two men working separately.

To obviate the difficulty about holding the plant, a contrivance called *Rebmann's plant-holder* is sometimes used in Germany for planting large transplants. It consists of a bent iron rod, with a sharp point for sticking into the ground, and with an arm stretching out at right angles, near the extremity of which there is a spring-clip for holding the plant at the required height directly over the centre of the pit. On the plant-holder being fixed and the plant set in it at proper height, the man is left free to fill in the compost and earth.

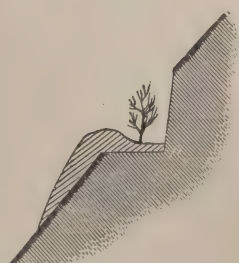
Another common German method with two- to three-year-old naked plants is is that of Biermann. The pits are made with the spiral spade (see Fig. 28, p. 359), and the plant is set with compost earth against one side, while the remaining space is filled up again with the earth taken out.

Planting with Mattock and Hoe.—On bare rocky soil, planting may often have to be performed with the *planting-mattock*. It is held like a common pick. A thin part of the turf is first pared off with the broad end, exactly where the tree is to be planted, and the soil is loosened to the depth of about 8 in., stones that might interfere with the planting being at the same time brought to the surface. Every two men with planting-mattocks should be followed by a boy or a man with a basketful of small seedlings and the *planting-hoe*. This he digs into each prepared spot, and then pulls it in a little, so as to make a sufficient opening to hold the roots of the seedling, which he inserts carefully with his left hand. As soon as the roots are in proper position the hoe is withdrawn, care being taken not to disturb the plant. He then gives the earth, upon the side of the hole next to him, a push with the lip of the hoe, to bring the loose earth into the hole about the roots, and finally the plant is firmed with the foot. In this manner three men will put out up to 2000 plants a-day (Brown, *The Forester*).

This method of hoe-planting is very much the same as that of the German planting-stick (Fig. 46); but the latter seems a somewhat simpler and handier instrument.

In pit-planting, it is important that the best soil should be put next the roots of the plants. Clods should be pulverised with the spade before the earth is put back. If merely replaced in lumps, vacant spaces will be left, where water can lodge and increase the danger from frost; but if the soil be packed firm about the tender roots, the lodgment of water is hindered and the danger of the soil being lifted by frost is minimised.

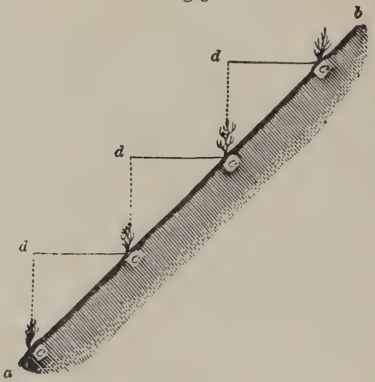
Fig. 51.



When planting on a hillside, the earth taken out of the pit should be put close to the lower edge; and when the plant is placed in the pit, the good soil should be well crumbled and put in about the roots. The soil not required for filling in is still left, forming a ridge to protect the roots from heat and to collect and retain moisture (see Fig. 51). These depressions also collect dead foliage, which decomposes and fertilises the soil.

In pit-planting in ravines and steep hillsides, the distance between plants should not be measured along the slope of the ground, but reduced to the level, as in Fig. 52. Here *a b* is a steep bank (45°) planted at 4×4 ft. (*c*, *c*, *c*, *c*). On the hillside the distance from *c* to *c* is $\sqrt{32} = 5\frac{2}{5}$ ft., and if the plants were put at 4×4 ft. along the slope, they would only have a lateral growing-space of $\sqrt{8} = 2\frac{4}{5}$ ft. instead of 4 ft. between rows.

Fig 52.



When pit-planting is done with balls of earth round the roots of the transplants, the compost and finer earth are put at the base and around the edges of the ball. Then the spaces between the ball and the walls of the pit are gradually filled up, the fine soil near the roots being worked in by hand and the coarser earth firmed with the handle of the hoe or a piece of stick to prevent the ball getting loose during dry weather, and the whole is trodden with the sole of the foot. If the soil is moist, the ball of earth may be kept somewhat above the ground-level so as to be better drained; while if the soil is dry, the ball may be placed somewhat lower than the ground-level, so as to hold moisture longer after rainfall.

4. **Tumping or Mound-Planting.**—In this method the roots of the plant are brought above the level of the soil, in place of being put in below it. It is a form of planting that is practically only in application on very damp soil, prone to rank growth of weeds, or on land having an unfavourable subsoil which it is not convenient to trench or plough up. It is not likely ever to acquire any very extensive practical application in Britain, for it is rather a costly method. With drainage, simpler methods of planting will usually be more successful, and not in the long-run more expensive.

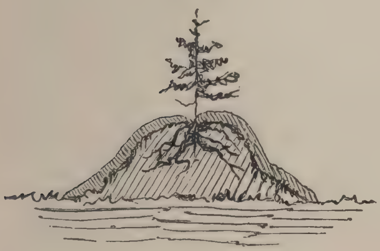
The soil has to be scraped together and arranged in a mound, of greater or less height according to circumstances. When the plant is brought into position, and the earth has been well placed round its roots, the whole is turfed over with the grass-sods cut away from the spot occupied by the mound (see Fig. 53). From the great amount of manipulation required, it can easily be understood that this method is somewhat expensive.

Some combinations of all the above methods can take place, as may be readily understood, without any detailed descriptions, from Figs. 54-56. In the first of these (Fig. 54), a combination of pitting and tumping is exhibited, in which the earth loosened from the pit is formed into a mound with a hollow encircling it, so as to retain rainfall: this method is adopted in Germany on very dry soil. A similar method is exhibited in the next illustration (Fig. 55), showing how large transplants hollowed out of the nursery-beds may be made into mound plants in shallow pits—a system said to yield good results in the Black Forest when old grass-lands, in situations exposed to late frosts, are being planted up.

The remaining illustration (Fig. 56) exhibits a combination of notching and tumping employed on old grazing-land and moist land overgrown with weeds.

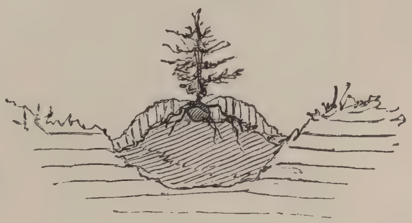
The sod of turf is turned back, so that its upper surface comes to lie on the face of the ground ; and then on this raised sod, of about 12 to 16 in. square, the plant is notched in by the ordinary method with the planting-stick or by means of a heavy notching-iron (Fig. 57) having a long stalk, and weighing from 16 to 22 lb. It consequently requires a strong man to work it with both hands ; whilst a boy inserts the plants in the manner already described as to the use of the planting-stick. The great point in planting with this instrument is to prevent any vacant space being left near the base of the roots of the plant. It is therefore necessary for the man to pull the top of the instrument towards himself when the plant has been inserted, shaken slightly, and drawn up to the position it should occupy in the ground. By this jerk he closes the lower earth against the deeper rootlets ; and then by pressing the handle of the notching-iron towards the plant, the upper

Fig. 53.



Ordinary method of Mound-planting with naked plants.

Fig. 54.



Combination of pitting and Mound-planting with naked plants.

Fig. 55.

Combination of Pitting and Mound-planting with balls of earth.

Fig. 56.

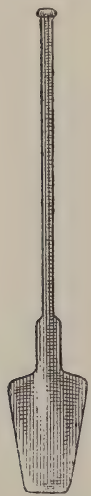
Combination of Notching and Mound-planting with naked plants.

portion of the root-system also becomes firmly fixed in the soil. A repetition of the pressure at a little distance helps to bind the soil, and to prevent a deep pocket being left for the lodgment of water.

Of course there is here a decided tendency towards pressing the roots into an abnormally flat shape not natural to young plants ; hence the method is only applicable to very light soil. Under such conditions it is, along with notching by means of the planting-stick, one of the most rapid and the cheapest methods. Where, however, small plants can be put out by means of Heyer's cylindrical spades, involving only small balls of earth round the roots, no method of planting can well be cheaper ; and by the adoption of this latter method there is an easy solution of one of the great problems of planting on soil of medium consistency—viz., how to plant up large areas of land, in a short space of time, and at a comparatively small outlay, so as to obtain satisfactory results. I recommend a trial.

Wisps of three or four seedlings or small transplants (of Scots Pine and Spruce only, never of Larch) are sometimes planted on the Continent in mountainous districts. The several plants shelter each other at first against drought, and one generally forges ahead in growth; but unless the weaklings are then thinned out, the young plantations soon become exposed to attacks of insects and fungous diseases. It is not a method that can be recommended for Britain.

Fig. 57.



Heavy Grubbing-iron also used for Notching.

A golden rule for planting is that *neither seedlings nor transplants should be planted deeper than they have stood in the nursery.* Deep planting is bad for all kinds of plants, but especially for Conifers, and among Conifers especially for Spruce; and it is more injurious on stiff binding soil than on light porous soil, where oxygen can circulate more freely. On sandy friable soil, deep planting, with a view to let the plants reach the fresher and moister layer, may only lead to wilting for a time, and it is better to have the plant wilt and afterwards recover than to have it killed outright by drought. But on stiff loam and clayey or limy soil, deep planting suffocates the root-system by removing it from the reach of the oxygen it has formerly been accustomed to. So unsuited can deep planting be to some plants, that they sometimes try to adapt themselves to the changed circumstances by developing entirely new roots at the old ground-level, as is shown in the reproductions of the photographs of Spruce in Fig. 58.

The following abbreviated notes concerning the practice in Germany with regard to woodland sowing and planting may perhaps interest British foresters (compiled from Lorey, *op. cit.*, pp. 494-506):—

Kind of Tree.	Sowing.	Planting.
A. *Broad-leaved Trees.*		
Oak . . .	By dibbling over large patches of good soil, or in bands or small patches. Best protection against weeds and frost if dibbled under light shade of standards.	Mostly with nursery-plants from 2-year-old seedlings to 3-year-old and older transplants, transplanted as 1- or 2-year-old seedlings. Plants generally pitted without balls of earth. Tap-root often inconvenient, and then shortened. Strong transplants require retransplanting and pruning.
Beech . .	Is usually regenerated naturally while clearing the mature woods. Broadcast sowing over whole area (after breaking up the surface-soil), or more usually only on prepared strips and patches.	Often with 1-year-old seedlings, but generally with 2- to 3-year-old plants. For filling blanks and underplanting, plants over 5 ft. high are often required.

Fig. 58.

Bad Results of planting Spruce too deep.

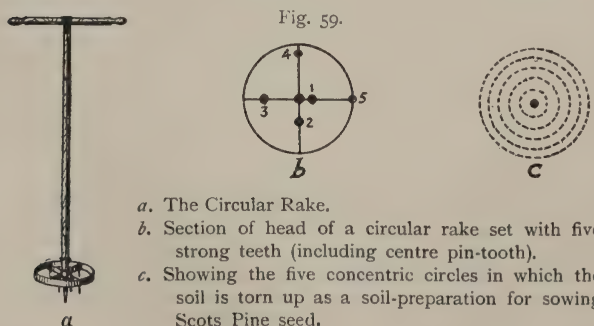
Kind of Tree.	Sowing.	Planting.
A. *Broad-leaved Trees*—continued.		
ASH . . .	Only exceptionally sown, on small patches.	With 3-year-old plants (1-year-2 transplants). Establishes itself easily.
ELM . . .	...	With all sizes of plants, from 1-year-old seedling upwards. Establishes itself easily.
MAPLE and SYCAMORE	Seldom sown, and *then* usually along with Ash on small patches.	Mostly with 3- to 4-year-old transplants.
HORNBEAM	Generally seeds itself on damp spots (sometimes more freely than is convenient).	With 2- to 3-year-old plants, usually taken from the woods, for underplanting Oaks in cold damp spots.
ALDER . .	...	With transplants of different sizes, planted mostly in autumn on mounds on swampy land, and often merely the truncated roots.
BIRCH . .	Usually sows itself far too freely, but is sometimes sown broadcast to raise shelter for other plants.	Mostly with self-sown plants taken from the woods in spring.
SWEET-CHESTNUT	Occasionally dibbled like Oak.	With 1- to 3-year-old (mostly 2-year-old) seedlings, dibbled *point downwards* in trenched seed-beds. From 1500 to 2000 2-year-old seedlings can be raised on one square perch (1089 sq. ft.) of seed-bed, at a cost of about 20s., or 12s. per 1000.
WILLOWS & OSIERS .	Tree-willows sow themselves freely along with other softwoods.	*Osiers.*—Best average results with 12-in. slips of 1- to 4-year-old wood set upright in deeply trenched beds in rows 20 × 4 in. Kinds recommended generally—*S. viminalis*, *S. amygdalina*, and hybrid *S. viminalis × purpurea*. The different kinds should be planted separately.
POPLAR .	Aspen usually sows itself more freely than is desired.	Preference always given to Black and Canadian Poplars (especially the latter). Thick slips are usually cut from stout shoots and planted, but smaller cuttings can first stand in nursery. In planting Aspen, suckers are mostly used.
B. *Conifers.*		
LARCH . .	Often sows itself on damp sunny spots. Otherwise sown broadcast or on patches with other seed (*e.g.*, 2 lb. Larch and 5 lb. Scots Pine seed to produce a mixture of about five to one, as the Larch germinates less freely than the Pine).	Mostly with 3- to 4-year-old transplants, and usually only interspersed among other trees (broad-leaved and conifer, and in copsewoods) individually, or in groups, or in rows, or along the edge of roads, &c. Here and there in pure woods, which are then underplanted at an early age.

Kind of Tree.	Sowing.	Planting.
B. *Conifers*—continued.		
SCOTS PINE	Natural regeneration is easy on good soil and in a damp climate. Sowings mostly either broadcast with cleaned (wingless) seed after slightly breaking up the surface-soil with a harrow, or made in rows by ploughing single furrows, or on small patches prepared with a circular rake.[1] For N.E. Europe, sowings on good soil are said to be much preferable to spring planting, as the latter does not produce such good timber for board-milling.	From 1- and 2-year-old plants, with naked roots, or with small balls of earth lifted with a 2-3 inch cylindrical spade (quick, cheap, and effective), up to large transplants. Naked plants are notched with wedge-spade, planting-stick, heavy planting iron, &c. Caution should be exercised in mulching the roots in loam before planting. Distance between plants varies: if planted as nurse to a shade-demanding species (Beech, Silver Fir), it should be planted wide.
AUSTRIAN & CORSICAN PINE.	...	Mostly 1- to 4-year-old plants used (Austrian for planting up steep limestone hill-slopes).
WEYMOUTH PINE.	Can sometimes be naturally regenerated with much success.	Mostly with 3- or 4-year-old transplants.

Organic Disturbance in Planting, and Trimming of Plants.—Whenever plants are transplanted, a certain amount of disturbance is caused throughout the organism; and in order to balance the derangement and injury which take place in the root-system, a corresponding trimming of the crown is required to curtail the demands of the foliage for food-supplies, and more

[1] In place of having a single head with regularly-placed teeth, as in the common rake, the *circular rake* consists of two iron heads crossing each other at right angles and bound together strongly with concentric iron circles. The 5, 9, or 13 teeth (according to the diameter of the hole wanted) are extra strong, and are so set that, in turning the rake round and round with its long lever handle, each tooth describes its own separate circle in tearing up the turf and soil, so that the soil is thus worked up in a series of close concentric circles corresponding to the number of teeth.

Fig. 59.



a. The Circular Rake.
b. Section of head of a circular rake set with five strong teeth (including centre pin-tooth).
c. Showing the five concentric circles in which the soil is torn up as a soil-preparation for sowing Scots Pine seed.

especially for water for the purpose of transpiration. The larger the class of transplant, the more likely is damage to occur to the roots; and consequently the greater is the need of adjusting the rate of transpiration to the new capacity for imbibition. All such deliberately inflicted injuries are, however, to a greater or less extent a drag on the normal development of the plants; hence, whenever possible, the use of small material and of simple methods of planting is advisable in preference to larger transplants and costlier methods of planting. But as large transplants must, from the rank growth on many classes of land, often be used, a certain amount of trimming can hardly be avoided. When the plants have in the nursery-beds formed long straggling rootlets, and these are not cut away by the spade in lifting them from the beds, then some of the roots may require to be cut back, as well as some of the twigs of the crown. For such trimming operations on young plants the use of *pruning-shears* is to be recommended (see p. 383); but care must be taken not to injure the leading-shoot.

Best Season for Planting.—Healthy plants may be transplanted at any season of the year; but it is only in accordance with the laws of vegetable physiology that the least disturbance in the organism should take place in autumn, just after the completion of the active period of vegetation, or in early spring, just before its commencement. Such disturbance is minimised when the plants are lifted with balls of earth around the roots, because there is then less interference with the normal balance between imbibition of water and food-supplies, and transpiration and assimilation in the foliage. When the balls of earth are of proportionate size to the plant, planting operations may even be carried out in summer, if necessary; and in places such as parts of the west coast of Ireland, where July and August are rainy months, while spring and autumn often bring dry cutting winds, July is perhaps the best season for planting, as soon as the summer rains begin. But, for various reasons as to climate, labour, and cost, planting throughout Britain is mainly carried out either in spring or in autumn. At these seasons the temperature of soil and atmosphere is not so low as to damage the plants during the planting, nor is the climate so dry as to exhaust them by excessive transpiration.

In favour of spring planting it may be said that, almost immediately after the transplanting, the young plants throw out their new roots and foliage and establish themselves on the whole more easily; whereas, if planted in autumn, they are more likely to be lifted by frost during winter, or to have their hold on the ground loosened by high winds. **In favour of autumn planting,** it is argued that the plants settle themselves in the soil during winter and begin to develop new root-hairs and suction-roots, so that they can therefore start growing more freely in the spring, and are better able to withstand heat and drought. **In practice, however,** if there be a large area to plant each year, it is best to do as much planting as can be done in autumn on stiff soil not liable to be lifted by frost, and with plants which flush their foliage early in spring.

Where planting is not extensive it is easy to choose one's time, as small batches of labour are easier to procure than large gangs of planters. But where 300 or 400 acres are in question, it is necessary to take advantage of the whole season from the middle of October till April, whenever the weather permits, so as to have the work done before the plants begin to grow about the middle or end of April. Of course the time varies with the climate: spring planting can continue a month later in Scotland than in the south of England.

Even when planting operations are confined to early spring, a commencement should be made with species of trees like Larch, Birch, Elm, and Chestnut, which break early into leaf; and the warmer exposures should all be planted before the colder hollows or northern aspects. As vegetation is not stimulated into activity so early on northern exposures, there is no necessity for their being planted so soon as the warmer localities. On the whole, deciduous trees flush their new foliage earlier than evergreen conifers. This point deserves attention, as well as the two facts that when Pine, Spruce, and Silver Fir have already begun to flush their new foliage, they possess a somewhat greater power of establishing themselves than is possessed by the majority of deciduous trees, and that if planted in autumn transpiration through the leaves goes on during sunny weather in winter, despite the disturbances caused by planting and any damage sustained by the roots. So far as individual kinds of plants are concerned, the older the plants are, the more nearly should the time of planting coincide with the most favourable season—*i.e.*, just before the opening of the buds in spring.

As a rule it is best, *cæteris paribus*, to confine autumn planting to deciduous kinds of trees, and to plant out all the evergreen conifers only in spring; for the latter are more shaken by wind in winter.[1]

In any case, however, planting can seldom be continued right through the winter into spring, as it is likely to be occasionally interrupted by hard frost. Local conditions of themselves mainly determine when the bulk of the work must be done.

Cost of Sowing and Planting.—Special remarks will be made in the next chapter regarding the rough average cost of forming extensive plantations on waste land (see p. 416), but no other general data of the probable cost of other operations in woodland or nursery can at present be given than are contained in the following Note. Unfortunately, it applies merely to German conditions, as no such comprehensive and reliable statistics of this sort have yet been compiled for any part of the United Kingdom, although various other useful data are given as to "Prices of Contract Work" in Webster's *Foresters' Diary and Pocket-book.*

[1] Recent investigations in France have shown that the growth of roots is not continuous throughout the year, but is interrupted by periods of rest, which do not, however, correspond exactly with those of the aërial portions (crowns). Among conifers, root vegetation is entirely suspended from November till March or April. Among broad-leaved trees there is no such total interruption; their roots can develop even in the middle of winter if the season be mild, but the month of February and the beginning of March are the times least favourable for root-growth. The decrease in soil-temperature causes growth to diminish during winter, and its total cessation among conifers is doubtless a natural adaptation to severe climates, which has become a hereditary property. This seems an additional reason why it is preferable to plant broad-leaved trees in autumn, and conifers in spring.

NOTE.

Cost of Soil-Preparation, Sowing, Nursery Work, and Planting.—As the outlay must vary with soil, subsoil, and local price of labour, no attempt to express the average cost in £ *s. d.* can be of any practical use. But in default of similar specific data for Britain, the following general averages for average conditions of soil throughout Western and Central Germany (compiled from *Forst- und Jagd-Kalender*) concerning the work expected of woodmen and the time-basis used in calculations for piece-work will be of interest, and possibly of practical value, for rough general guidance :—

I. Basis of Payment for Soil-Preparation.

A. **Manual Labour.**	No. of days of a man's work. Per acre.
1. *Raking*—	
(1) Over whole area undergoing natural regeneration	2-5
(2) Preliminary raking before broadcast sowing	1·2
(3) Raking-in seed in strip-sowings (20 in. broad and 52 in. apart)	0·4
2. *Hoeing* (rates varying according to the stiffness of the soil)—	
(1) Breaking-up and turning over soil with the broad hoe ; for area actually hoed	12-28
(2) Superficial breaking-up of the soil	10-14
(3) Hoeing seed-drills in Beech-woods on steep hillsides (40 in. from centre to centre and up to 4 in. deep)	4·8-9·6
(4) Clod-hoeing in Beech-woods on soil overgrown with grass, over one-third of the area	8-12
(5) Deep-hoeing, and loosening and turning over soil to a depth of 8-12 in. (seed and transplant beds)	40-80
(6) Hoeing strips 20 in. broad and 6½ ft. apart from centre to centre, to a depth of 16 to 18 in.	7-11
3. *Digging*—	
(1) Trenching to a depth of 8 in. (seed-beds, strips for sowing acorns, or for planting)	8-12
(2) Digging-ditches 17-20 ft. apart and 1 ft. deep, and spreading the earth equally over the intervening space to a height of about 1½ in.	12-16
4. *Hand-trenching*—	
(1) Over whole area, to a depth of 12-20 in.	60-120
(2) In narrow strips (20 in. broad and 16-20 in. deep, with 5 ft. of clear space between)	14-15
(3) In broad bands on moorpan lying at a depth of 24-40 in. (bands up to 8 ft. broad, with 6-6½ ft. of clear space in between)	56-72
5. *Making Ditches and Mounds on Moorpan* (rates varying according to the stiffness of the soil)—	
(1) Digging ditches 40-48 in. wide, breaking through the pan at about 1 ft. deep, and spreading the earth on the intervening mounds 13-17 ft. broad	56-72
(2) Throwing up mounds 40 in. broad and 8 ft. from centre to centre	48-80

B. **Draught Animals** (Horses and Oxen).	No. of days' work of a pair of horses or oxen. Per acre.
1. Ploughing whole of land reverting from agriculture	0·8-1·2
2. Ploughing strips or bands, at same rate for area actually ploughed	0·8-1·2
3. Running furrows 4-5 ft. apart with a forest-plough (0·4 to 0·8 of a man's day is also needed when there are many roots in the soil)	0·8
4. Subsoil ploughing (with soil and subsoil coulters) to a depth of 20 in.—	
(1) On 0·6 of the whole area, free from moorpan	1·2
(2) do. there being moorpan to break through	4

II. Basis of Payment for Sowing.

	No. of days of a man's work. Per acre.
1. Dibbling acorns in strips 5 ft. apart	1·6
2. Sowing Scots Pine seed in strips	0·8
3. " " " with the seed-horn	0·2

III. Basis of Payment for Planting—*Exclusive of Cost of Lifting and Packing (see p. 385) and Transport.*

	No. of days of man's work.
Oak.	
1. Planting 1- or 2-year-old plants—	
(1) Notching in prepared soil (*e.g.*, 1 ft. broad, trenched strips), per 1000	1½
(2) Planting in open trenches 12 in. wide and 16 in. deep—	
(*a*) Preparing trenches for every 100 running yards	1·25
(*b*) Planting per 100 plants (40 in. apart)	0·4
(*c*) *Total cost* for every 100 plants (121 running yards)	1·9
(3) Transplanting 1- and 2-year-old seedlings into nursery-lines, per 1000	0·2-0·3
2. Planting transplants from 20 in. to 5 ft. high—	
(1) Planting at 40 in. apart in open trenches 20 in. in depth and width—	
(*a*) Preparing trenches per 100 running yards	2·5
(*b*) Planting per 100 plants (40 in. apart)	0·8
(*c*) *Total cost* for every 100 plants (121 running yards)	3·8
(2) Pit-planting, per 100 plants	2-3
3. Planting large transplants, 5-8 ft. high. (A 2-horse cart can carry about 200 such plants)—	
Pit-planting in holes 24 in. square, per 100	3-5
Mound-planting, per 100	4-8
4. Planting extra-large transplants, 8-12 ft. high. (A 2-horse cart can convey from 50-100 such plants), in pits about 27 or 28 in. square, per 100	5-10
5. Planting Oak-roots for coppice, per 100 plants as thick as one's thumb	0·8-1·5
Beech.	
1. Planting 3- to 5-year-old plants in wisps of 3-5, per 100 wisps	0·8-1·5
2. Planting transplants, 20 in. to 5 ft. high, per 100	1·5-3
3. Planting larger transplants, 5-8 ft. high, per 100	3-5
Ash, Maple, Sycamore, and Elm (same as for Oak and Beech).	
Alder.	
1. Planting transplants, 20 in. to 8 ft. high, per 100	1·5-4
2. Turf-mound planting in marshy places, per 100	1-2
3. Planting roots for coppice, per 100	0·8-1·5
Birch (same as Alder for 1 and 3).	
Willows for pollarding.	
Preparing holes, cutting, trimming, and planting sets of 10-12 ft. long in pits 20 in. broad and 16 deep, per 100	2·5-3·5
Willow-beds.	
1. Planting cuttings on mounds 16-17 ft. broad, with ditches 2-8 ft. wide, cuttings 1-2 ft. long, set 12 in. apart, in rows 20-24 in. apart, per acre	96-120
2. Planting cuttings in clusters, in pits of 12-16 in. square, at a distance of 3½ to 4 ft. from centre to centre of squares, per acre	48-56
3. Layering and pegging down Willow-shoots in small grooves cut perpendicularly, per 100	1-1·5
Scots Pine.	
1. Planting 1-year-old seedlings—	
(1) Notching into soil not specially prepared, per 1000	1
(2) Notching in pits prepared to a depth of 10-14 in., per 100	0·3-0·6
(3) Planting in trenched pits 16 in. square and 16-20 in. deep, per 100	0·8-1·3
2. Planting 2-year-old seedlings, with naked roots in prepared pits, on bold strips, or on mounds, per 100 (for planting only)	0·5-1
3. 3- to 4-year-old transplants, with balls of earth—	
(1) Planting with the common spade, per 100	0·8
(2) Planting with the cylindrical spade, per 100	0·6
Spruce.	
1. Notching on unprepared soil, per 1000	0·9-1
2. Planting 4- to 6-year-old plants, per 100	0·4-0·5
3. Planting in wisps or prepared soil, per 100 wisps	0·5-0·75
4. Mound-planting with 3-year-old plants, per 100	1-1·5
5. Turf-mound planting, per 100	0·75-1
6. Planting with balls of earth, per 100	0·75-1
7. Transplanting seedlings into nursery-lines, according to method	0·4-1

The Cost of Cultural Operations in Southern Germany may also be of interest to foresters in Britain (Gayer's *Waldbau*, p. 597):—

A man's	wage is calculated at	1s. 9d.	per diem.
A woman's	" "	1s. 3d.	"
The hire of a 2-horsed cart is		9s.	"
" 1	"	4s. 6d.	"

A. **Sowing in Woodlands.**	
1. *Sowing broadcast* on soil from which the stumps have been grubbed up	Per acre. £0 3 8 to 0 4 0
2. *Sowing in drills* after preparing the soil in strips 2 ft. broad and 4 ft. apart	0 16 0 to 1 4 0
B. **Nursery Work.**	
1. *Cost of forming nurseries*—	Per 36 cubic ft.
(*a*) Preparing compost-heaps	0 1 8 to 0 2 0
(*b*) Earth-work—consisting of turning over the soil twice (in summer and the following spring) with the spade to a depth of 12 to 16 in.; clearing the soil of roots, knocking out the earth from the turf-sods, burning the roots and turf, and spreading the ashes over the whole soil; preparing the soil with the iron rake, laying it out into squares, and forming the beds and the paths between them	Per acre. 7 14 0 to 8 0 0
2. *Sowing in nurseries*—*i.e.*, strewing the beds with searched (screened) compost, pressing in the drills with sowing-boards, and sowing the seed carefully, covering up with compost-earth and turf-ashes, and turning over the soil of old seed-beds .	2 16 0 to 3 0 0
3. *Transplanting* 1- or 2-year-old seedlings from the seed-beds into the nursery-lines, and strewing compost over the beds at the end of June .	Per 1000. 0 2 0 to 0 2 6
C. **Planting.**	
1. *Planting* yearling Pine, Oak, Alder; 2-year-old Beech, Spruce, Maple, Sycamore, Alder, Ash; 3-year-old Silver Fir, &c., without balls of earth, from the seed-beds to open grassy land by means of the small cylindrical spade, and applying compost to them	0 4 0 to 0 4 6
Planting alone, without any application of compost-earth	... 0 3 0
Planting, with application of compost, on very strong and binding land, hard to work . . .	0 8 0 to 0 9 0
2. *Planting* as above on very grassy land, and including the preparation of the soil in the previous autumn, by means of turning back the sods of turf in pieces of 18 in. × 10 in.	0 8 0 to 0 10 0
Planting as above on strong and binding land, difficult to work, and apt to damage the planting implements	0 19 0 to 1 0 0
3. *Planting* of transplants 2 to 3 ft. high and with balls of earth, including transport from the nursery and soil-preparation in the previous autumn . .	0 14 0 to 0 18 0
4. *Planting* broad-leaved transplants of 3½ to 5 ft. high—especially Ash, Elm, Maple, in Willow and Poplar coppices—without balls of earth, and including soil-preparation in autumn and transport from the nurseries	1 0 0 to 1 5 0
5. *Planting* cuttings of Willow and Poplar in trenches 1 ft. deep and 40 in. apart, to form coppice; this includes cutting the slips in February, sheughing them till required, preparing the trenches, and covering the slips with earth . . .	Per acre. 0 17 0 to 1 0 0

CHAPTER IV.

THE PLANTING OF WOODLANDS.

The Selection of Trees for Planting.—It is a principle in Sylviculture that, to ensure continuity in yield, only trees which are able to protect the productivity of the soil should be grown as timber-crops. Subject to this primary condition, a choice may be made between the several species of trees suitable for growing either in pure or mixed woods. If plantations be made of *light-demanding* trees, when once they begin to exhibit natural demands for increased individual growing-space as young trees of twenty-five to thirty (Larch and Scots Pine) or fifty to sixty years (Oak), then the productivity of the soil can only be safeguarded by underplanting.

It is impossible to forecast the prices that will be obtainable for different kinds and sizes of timber fifty or sixty years hence. But judging from past timber prices, and from the prospects of something very like a timber-famine in the near future, it is almost certain that all kinds of timber-crops—Oak and mixed hardwoods; Larch, Pines, Spruces, and Silver Firs; and more particularly trees like Douglas Fir and Menzies Spruce, which attain good marketable dimensions within forty to fifty years—offer good prospect of fair profit. On suitable soil no tree is more profitable than Poplar.

In growing timber for profit, the main common-sense principle is of course only to plant such trees as are likely to be saleable at a fair price, and as are well suited to the given soil and situation. Neglect of either of these points must end in loss. There is no use in growing the finest of Beech if only Oak and Ash can be sold at any fair price, or of trying to grow Oak or Ash as the bulk of the crop if the land is really only suitable for Beech as the chief tree in the woods. And if the land be poor and only suitable for Pines, Firs, and Larch, it is useless to try and grow crops of more exacting trees.

The net value of any timber-crop, no matter where situated, depends far less on the kinds of trees planted than on the local demand for timber and on the quality of what is offered for sale. The only sound advice that can therefore be given is to plant merely those trees for which the given soil and situation are best suited. In all large towns there is a constant demand for Larch, Scots Pine, and Spruce; and wherever the soil and climate are adapted for growing crops of these, they generally pay as well as, or better than, any other sort of timber-crop, seeing that their growth is quick. Oak is always in demand for various purposes, and so is Ash for agricultural implements, coach-building, &c. Despite the long time (100 to 150 years) it takes to reach a fair size, Oak is still likely to pay fairly well on good, heavy, well-sheltered land in a warm part of the country; and Ash is safe to pay on land adapted to it, as, for instance, in dells, coombes, and other local hollows having a good, strong, fresh, or moist loamy soil. Elm is also much used in large towns, and can be grown with profit on a loamy soil.

In large towns a great quantity of fuel is consumed. Where coal is plentiful, wood is here never grown for firewood, as throughout continental Europe, only the lop and top being usually sold for this purpose. But in some parts of England (*e.g.*, Suffolk) where coal is scarce and dear, coppice-wood is regularly sold as fuel, all the straight rods being utilised as hop-poles, bobbin- and crate-wood, hoops, poles, implement-handles, besom-spray, &c.; and when the best of the wood has been picked out for these purposes, all the rest is bundled up and sold as pimps or faggots. On poor land and low swampy ground not suited for large timber, a **coppice**-crop like this answers well enough, and is still sometimes profitable; but on land of fair quality, highwood plantations are usually more profitable.

In mining districts large quantities of wood are required for pit-props, consisting of mature timber, thinnings, and top-ends down to not less than 3 inches in diameter at the small end. Oak is the best of pit-wood, as it can be shortened and used a second time; but Larch of 3 to 5 inches top-diameter is chiefly used as props, and when of about 8 inches in diameter, it is also used as small sleepers for underground tramways in mines. When full-grown and mature, it is used for railway sleepers and boards, &c. Scots Pine ranks far below Larch in price and general utility, but is also used for propwood, sleepers, and boards. Poplar and Willow are often also in fair demand, particularly when yielding good large scantling used for waggons and planks. Indeed, in mining districts thinnings of almost every kind are usually saleable if averaging from 3 to 5 inches in top-diameter. Near calico and linen manufactories there is always a demand for about 6-inch bobbins of Sycamore, and a smaller size of Birch. For calico-rollers of about 9 inches in diameter and above, Sycamore is very highly paid, 3s. 6d. to 5s. 6d. per cubic foot being by no means an unusual price for fine quality of timber near Dundee.

So far as any broad rough generalisation can be made, it may be said that, as a rule, *broad-leaved crops* are those which yield the greater profit on good stiffish loam and clay soil that is fresh and moist; that *conifers* are usually by far the most profitable timber to grow on poorer, lighter, loamy, and sandy soil, particularly if it be not fresh and moist enough for broad-leaved trees; and that on limy soil and chalk Beech should usually form the main crop, with other hard woods interspersed throughout it, unless the land is so deteriorated that only Austrian Pine can thrive there in the meantime.[1]

[1] *German yield-tables* show that, on soil of average quality for the given kind of tree, well-managed woods of "Larch and Ash give the greatest average production under a rotation of about 70 years; Scots Pine about 80 years; Spruce, 90 years; Beech and Silver Fir, 120 years; and Oak, 130 years. On fertile soil the culmination occurs earlier, and on inferior soil later. If worked under that rotation, we can count on an average production in the way of timber as follows: Ash about 40 cubic ft. per annum; Oak, 46 cubic ft.; Beech, 57; Scots Pine, 70; Larch, 73; Spruce, 84; and Silver Fir about 111 cubic ft. per annum" (Schlich in *Trans. Roy. Scot. Arbor. Socy.*, 1904, p. 193).

Now, if the average selling-price be taken at 1s. 6d. a cubic foot for Oak and Ash, 1s.

In technical value and money return obtainable per unit of volume, none of our indigenous timbers equals the Oak; whilst for furniture and ornamental purposes, Ash, Maple, and Red Elm approach nearest to it. For the manufacture of agricultural implements, and for similar purposes requiring toughness combined with lightness, Ash timber has a value specially its own. Among Conifers, good, sound, large-hearted Larch is of highest value, and then Douglas Fir, while Pine, Spruce, and Silver Fir vary locally in price. But as Spruce and Silver Fir are so much more productive per acre than other Conifers, the large supplies of their timber annually thrown into the Continental market may account for the comparatively low prices. The money return available in general from the softwoods depends to a very great extent on local conditions of the timber market; whilst the Beech usually yields comparatively poor returns, despite its being the best and the most heat-producing kind of fuel obtainable from woodlands. Its timber is, however, now coming largely into demand again. (*Studies in Forestry*, p. 167.)

Soil-Preparation before Planting does not usually require to be on anything like so extensive a scale as for sowing, and this is one of the advantages of planting. In either case, however, wet land has to be drained, rough heather-grown moorland has to be cleared and burned, and often opened up, moorpan tracts have to be trenched to break up the impervious pan, and loose shifting sand has to be fixed to a greater or less extent before woodlands can be formed with any fair chance of success.

Whether such special work on any very extensive scale should be done long before the planting or immediately preceding it, depends on circumstances. Drains need time to be thoroughly effective; and the more binding the soil, the more beneficial is the action of winter frost in mellowing and improving it. Drainage, trenching, and binding of sand require to be done at least six months or more in advance; but if small pits only have to be opened, they may become filled with water (on stiff soil), or the sides may crumble and fall in (on loose soil), in either of which cases it is usually best to open them just before planting.

The best Distance for Planting should be well considered before any landowner commits himself to a permanent investment of this sort. The three main considerations concern (1) *the cost of planting*, (2) *the probable profit*, and (3) *the increase and maintenance of soil-productivity*.

1. *The cost of planting* will be least when small plants can be used. Notching with naked seedlings on light sand is the cheapest form of planting that can be conceived, and next to that comes the use of small plants with

for Larch and Beech, 9d. for Scots Pine, and 6d. for Spruce and Silver Fir, then the highest average return above shown is, per acre per annum, Larch 73s., Oak 69s., Ash 60s., Beech 57s., Silver Fir 55s. 6d., Scots Pine 52s. 6d., and Spruce 42s.,—the Ash and Larch being presumed to give this at 70 years, Scots Pine at 80, Spruce at 90, Beech and Silver Fir at 120, and Oak only at 130 years. But as a matter of fact, Larch, Pine, and Fir woods in Britain usually reach their maturity between 40 and 60 years of age, so that two or three crops of these may be had for one of Oak or Beech, and less capital is therefore locked up meanwhile, so that the Conifers should be by far the more profitable.

Full details for working out such forecasts will be found in vol. ii. Part V., *Management of Woodlands*; but it may here be pointed out that neither these German statistics as to rate of growth nor the present price of timber in England can be used indiscriminately as the basis of calculation for timber crops in this country. For example, neither Spruce nor Silver Fir grows anything like so well here as in Central Europe. One must take such statistics merely as rough indications for general guidance; and as such, of course, they have a certain minor value.

balls of earth lifted with Heyer's cylindrical spade (see p. 382), and planting in holes made with the same. The larger the plants, and the closer they are planted, the greater must necessarily be the cost of planting.

2. *The probable profit* of any plantation depends mainly on the local market for thinnings and for mature timber. One cannot plant simply the number of trees that will form the mature crop. Of the far larger number originally planted, only a small proportion of the fittest survive to the end, and the others have to be thinned out from time to time. If, therefore, the soil and situation do not of themselves necessitate close planting (as, say, at $3\frac{1}{2}$ or $3\frac{3}{4}$ ft. apart in squares or triangles on poor exposed land), the market for thinnings may well be considered before one decides on planting at 4×4 ft., or at $4\frac{1}{4}$, $4\frac{1}{2}$, $4\frac{3}{4}$, or even 5 ft. apart. If there is a good local market for thinnings, close planting will be profitable; if not, then in place of being profitable it must cause a double loss, because, while costing more, it will lead to the landowner being forced, sooner than otherwise necessary, to incur expense in thinning the young plantations without being able to dispose of the small poles with advantage.

3. *With regard to the productivity of the soil*, the main object should be to try and get the ground completely covered by the crop within from five to ten years, under ordinary average circumstances, while sufficient individual growing-space must at the same time be assured to each pole between the tenth to about the fifteenth year, after which time (even with fairly wide planting) the struggle for existence will have to be shortened artificially by thinning out such poles as are now superfluous.

In this respect the various sylvicultural characteristics of different woodland trees have special importance. Light-demanding trees of rapid growth (*e.g.*, Larch and Birch) should not be planted so close as those that are slower in growing at first and endure shade better (Spruce, Silver Fir, Douglas Fir, Beech); while trees prone to spread at an early age (*e.g.*, Oak and Scots, Austrian, and Corsican Pines) require to be planted close to check this branching habit. But with every tree it is necessary to limit lateral expansion by circumscribing the average growing-space per stem, so as to force on the growth in height and get the full advantage of a long, straight, clean stem before a very much larger amount of light and air has become a *physiological necessity* after the first thirty or forty years (with most Conifers, most hardwoods, and all softwoods), or forty to sixty (in Oak and Beech, Spruce, and Silver Fir).

The theoretical point of view may be stated as follows :—

The **density of the crops** is a factor which exerts no little influence on their development and ultimate remunerativeness. Crowded woods have practically no greater total enjoyment of light, warmth, atmospheric food, and soil-nutriment than less densely packed crops growing in closed canopy; and as the production of timber is distributed over a smaller number of individual stems, the share which each is capable of receiving is greater than when the total of the available food-supplies has to be divided by the larger number. At the same time, in close-canopied, but not crowded, woods, the natural selection of the predominating stems to form the future mature crop proceeds more rapidly, as the individuals of forward growth utilise somewhat above their average share of light, &c., and consequently have a larger annual increment than if the struggle for life and domination were more prolonged by having to be waged against a larger number of individuals of equal vigour. Where, owing to wide planting, the canopy is not of full normal density, the productive capacity of the soil and of the atmosphere is not utilised economically; hence a loss in timber takes place which might easily be avoided. The earlier the young growth forms close canopy, the thinner are the branches formed, and the sooner do they die and drop off. A normal density of canopy therefore increases the technical value of timber by the production of clean boles having a high form-factor, and approximating, more than otherwise would be the case, to the cylindrical shape represented by 1·0. All crops intended for timber production should, therefore, be maintained in close canopy till they have entered the pole-forest stage of growth. This is more particularly important with coniferous trees, whose technical, and consequently monetary, value is dependent, to a considerable extent, on freedom from hard horny branches and knots. And it is, of course, all the more necessary in the case of shade-enduring trees, whose lower branches are longer retentive of life. Where, therefore, the early attainment of full normal canopy can be achieved without special outlay at the time of the young crop being formed, it is undoubtedly of great advantage to see that steps are taken to secure this end. Now, with this object in view it is by no means necessary to crowd plantations; for it is quite sufficient if the twigs and branchlets die off before becoming strong enough to leave snags or rotten ends in the timber, and if they can be displaced by the new annual zones of wood. This period varies with the different kinds of forest-trees. The branchlets of the ring-pored, broad-leaved species of trees rot much sooner than those of conifers; small twigs of Oak or Beech snap off through their own weight when they have been dry for two or three years; whilst similar twigs of Spruce remain often as snags for ten or fifteen years, and get partially embodied in the stem if not removed. For the production of clean boles, therefore, Conifers, and in particular the shade-enduring kinds, should be maintained in close canopy considerably longer than broad-leaved trees. (*Studies in Forestry*, pp. 167-169.)

Naked seedlings can, of course, be very cheaply notched at 3 ft. apart (4840 per acre, costing about four days' work of a man and a boy); but taking the three main factors of *cost*, *probable profit*, and *soil-productivity* into consideration, it will be found that, *for ordinary planting with transplants from* 1 *to* 3 *ft. high*, 4 × 4 *ft. in squares* (2722 *plants per acre*), *is, on the average, usually about the best distance for planting in Britain on medium classes of land for the given kind of tree.* On exposed sites and hot southern or south-western aspects, closer planting (say 3½ to 3¾ ft. apart) may sometimes be advisable, especially if there be a fair chance of selling early thinnings; but good soil, a sheltered situation, the use of large transplants, and a poor market for young poles, will often render advisable 4⅓ or 4½ ft., or sometimes even 4¾ or 5 ft., in squares (1742 plants per acre), or up to 6 ft. in triangular or quincunx planting.

Brown's recommendations were, that on low-lying and naturally sheltered land, broad-leaved trees should be planted at 15 ft. apart, and made up with nurses to 5 ft. over all; that on moderately sheltered parts they should be planted at 12 ft. apart, and made up with nurses to 4 ft. over all; and that on high-lying and exposed parts Pine and Larch only should be planted, and at distances varying from 3½ to 4 ft., as the case may be. (*The Forester.*)

Investigations at the Saxon Forest School (Tharandt) have shown that, on the whole, planting at 4⅓ × 4⅓ ft. apart is the most profitable distance—and this even in a country where early thinnings are always saleable. But even in Germany such mathematical solution of an important practical problem is not universally accepted, and close planting is generally preferred.

For planting in Germany, Gayer (*Waldbau*, 1889, p. 355) recommends the following distances, subject of course to variations according to the nature of the soil and the situation :—

	From feet.	To feet.
For Oak and shade-enduring plants.		
Seedlings under 8 in. high	1 × 1	2 × 2
Small transplants, from 1 to 2 ft. high	2 × 2	2¾ × 2¾
Stout transplants, from 3 to 4 ft. high	2¾ × 2¾	4 × 4
Very large transplants, from 6 to 8 ft. high	4 × 4	10 × 10
For light-demanding plants.		
Seedlings (Scots Pine, Larch), under 8 in. high	1¾ × 1¾	3⅓ × 3⅓
Medium transplants, from 2 to 4 ft. high	3⅓ × 3⅓	5 × 5
Stout transplants, 6 ft. high and above	5 × 5	as desired.

Lorey remarks (*Waldbau* in *Handbuch*, &c., p. 491) that, "In general one has more and more given up very close planting, because, apart from its heavy cost, it too soon leads to unsatisfactory development of the individual plant, while a good medium distance brings early enough canopy and ensures conservation of soil-productivity. But the number of plants per acre must not be reduced too far, and in most cases it should not be below 1600-2000 per acre"—*i.e.*, about 4¼ to 5¼ ft. apart at most. And he adds, "On the average, 3⅓ × 3⅓ ft. is somewhat close, and 4 × 4 ft. can be called the mean average."

In France planting is, on the whole, wider than in Germany. Thus Boppe et Jolyet (*Les Forêts*, p. 395) remark that—

> To quote specific figures, we recommend for all kinds of trees a distance of 5 ft. between plants, in lines 6½ ft. apart—or at least 5 ft. in squares.

In Britain planting is usually done either in *squares* or in *equilateral triangles*, which both form parallel rows of plants. For planting in squares, the number of plants required per acre is 43,560 (the number of square feet in an acre) divided by the square of the distance from plant to plant. For planting in equilateral triangles, the number of plants required is $43{,}560 \div (\text{square of distance} \times \sin 60°) = 43{,}560 \div (\text{square of distance} \times 0{\cdot}866) = (43{,}560 \div \text{square of distance}) \times 1{\cdot}155 =$ number of plants required for planting in squares $\times\ 1{\cdot}155$.

The triangular arrangement utilises the area to the fullest extent, but it needs more plants, and is more expensive and more difficult to plant regularly; planting in squares is easier.

On broken stony ground, however, planting cannot be done with anything like mathematical regularity, for the plants must be put in where there is soil.

The Number of Plants required per statute acre for planting in squares is as follows :—

Distance from plant to plant (in squares). Feet.	No. of plants required per acre.	Distance from plant to plant (in squares). Feet.	No. of plants required per acre.	Distance from plant to plant (in squares). Feet.	No. of plants required per acre.	Distance from plant to plant (in squares). Feet.	No. of plants required per acre.
1	43,560	6½	1,031	12	302	17½	142
1½	19,360	7	889	12½	270	18	134
2	10,890	7½	774	13	257	18½	127
2½	6,970	8	680	13½	239	19	120
3	4,840	8½	603	14	222	19½	114
3½	3,556	9	537	14½	207	20	108
4	2,722	9½	482	15	193	22	90
4½	2,151	10	435	15½	181	24	75
5	1,742	10½	395	16	170	26	64
5½	1,440	11	360	16½	164	28	55
6	1,210	11½	329	17	150	30	48

The Number of Plants required per acre for planting in equilateral triangles is as follows:—

Distance from plant to plant (in equilateral triangles).	No. of plants required per acre.	Distance from plant to plant (in equilateral triangles).	No. of plants required per acre.	Distance from plant to plant (in equilateral triangles).	No. of plants required per acre.
Feet.		Feet.		Feet.	
3	5,590	5	2,012	7	1,026
3½	4,107	5½	1,663	7½	893
4	3,143	6	1,397	8	785
4½	2,484	6½	1,190	8½	696

Note.—In Germany *double squares* (*quincunx*) plantations are sometimes formed by making large squares (say of Spruce) and putting another plant (say a Larch) in the centre of each square, thus forming double squares, and requiring practically very nearly the same number of each kind of plant as for planting in squares.

Supply of Plants.—If only small areas are to be planted yearly, it will probably be most convenient, and often also cheapest, to get the supply of plants from nurserymen. Or at any rate, the required supply of one- to two-year-old seedlings can be bought and planted closely in temporary nursery-lines in a suitable sheltered part of the land to be planted two to three years later (see p. 362).

Whether raised in home-nurseries or purchased from nurserymen, the seedlings or transplants used in forming plantations should have good well-developed roots, a stout well-set stem, and a fair proportion of foliage. They should neither be long spindle-shaped plants, drawn up by overcrowding, nor have a rich rank look, acquired in highly manured seed-beds and nursery-lines.

In the great majority of cases well-proportioned two- to four-year-old plants of medium size are the most satisfactory for planting,—unless for notching on sandy soil, when two-year-old Scots Pine are handiest, or when Silver Fir is being planted, when five- to six-year-old transplants are usually required. But in any case only good plants should be used, and it is far better to cast puny weakling transplants on the waste-heap (unless good enough for retransplanting for another year) than to put them into the plantation. Roughly speaking, therefore, up to about 10 per cent more plants should be provided than are actually needed for stocking the area, and the remainder can be kept on hand, either in the home-nursery or in a temporary nursery in a conveneint part of the plantation, to supply material for filling blanks during the two to three years after planting. Thus, say, planting is at 4 × 4 ft., then 2722 plants per acre are required to stock the plantation; but it is best to provide 3000 per acre, and keep 10 per cent (272) of the smallest and least vigorous in a small temporary nursery to replace casualties due to drought, frost, &c.

The best Time for Planting on any large scale depends on the available supply of labour. The advantages and drawbacks of spring and of autumn planting have already been mentioned (see p. 399), and generally it will be found advisable to have at any rate some part of the work done in autumn.

Every experienced planter who has had occasion to employ a considerable number of men, in order to get through his work as fast as possible, is aware of the difficulty there is in getting a large number of labourers properly qualified to do the work as it ought to be done. Common labourers are seldom acquainted with planting, and require more than a week's practice before they can be trusted to work properly. When inexperienced men plant, the work is nearly always badly done, and seldom satisfactory. In extensive planting, therefore, as much of the work should be done in autumn as is convenient, so as to prolong the planting season and get the work done with a limited number of experienced hands.

In planting extensive areas, if only a few good hands are obtainable, it is neither necessary nor advisable to begin at one part and proceed regularly over the whole area. There is generally variation in soil and situation, and when the weather is fine the men may be set to plant on the most exposed parts; and when the weather is cold or wet, they may be told off to plant the sheltered parts. Again, when frost comes on, and planting is interrupted, they may be put to such other work as thinning, road-making, &c., which can easily be done during hard weather. In this way ten experienced hands will do far more work in four months than twenty inexperienced men in two months; and the work will be better done and more satisfactory in the end. A good common-sense rule is to plant dry land in autumn, and cold stiff land in spring; also to plant the former in wet weather, and the latter in dry weather. (Brown, *The Forester.*)

In forming mixed Plantations, it has hitherto been customary in Britain to make them with a sort of stencil-like regularity, as shown in the following diagram (Brown):—

Fig. 60.

⊙ Oak, ● Ash, + Elm, ⊕ Sycamore, — planted at 24 ft. apart.

* Larch nurses, planted at about 4¼ ft. from hardwoods.

• Scots Pine nurses, planted at 6 (and 8½) ft. from hardwoods.

Although this may appear a good practical method, it is, however, really not at all a sound one to act on. It certainly enables the forester to estimate easily the exact number of plants he will require per acre, and for the whole area. But on large areas of true forest-land soil is seldom homogeneous; it varies in composition, depth, moisture, and other physical properties. Here, there is a patch of good soil; there, close by, it is not as good; in some spots it is moist, in others dry; and the forester notes these varying conditions, and tries to utilise to the best advantage the soil on each patch. But this can only be done by judicious admixture of the different species, here in small groups or patches, there in individual plants only; and such a sylvicultural principle is merely in imitation of the natural method.

When small poles from early thinnings between about fifteen and twenty years of age are not likely to be readily saleable, planting in *rows* or *lines*, giving a long rectangular growing-space to each plant, may sometimes be preferable to planting either squares or triangles.

For example, if it has been decided that about $4\frac{1}{2} \times 4\frac{1}{2}$ ft. (2151 per acre) is perhaps the best number per acre, when early thinnings have to be made about fifteen to twenty years of age, the removal of, roughly speaking, every alternate tree (viz., 1, 3, 5 . . . in first line; 2, 4, 6 . . . in second, and so on), and leaving one-half of the original number planted,—thus forming a young wood consisting of 1075 poles per acre standing in double squares (*quincunx*) of 9 ft. and at a distance of 6·36 ft. from plant to plant with an individual growing-space of $40\frac{1}{2}$ sq. ft.,—may perhaps seem less desirable than planting in rows at 5×4 ft. apart (2178 per acre); because if one has then to remove every alternate plant in the rows, this takes away 1089 poles per acre and leaves 1089 standing at $8 \times 5 = 40$ sq. ft. of individual growing-space, which will perhaps give a slightly better distribution with a view to subsequent thinnings. The thinnings, between twenty and thirty years of age, would probably leave the wood at $9 \times 9 = 81$ sq. ft. (537 poles per acre) and $8 \times 10 = 80$ sq. ft. (549 poles per acre), and the ultimate mature crop would probably be somewhat heavier in the latter than in the former case.

This savours, however, more of academic theory than of real practical utility.

Number of plants required per acre in row or line planting.

Distance between		Individual growing-space.	No. of plants per acre.
Lines.	Plants in lines.		
Feet.	Feet.	Sq. feet.	
4	3	12	3630
5	3	15	2904
5	4	20	2178
6	4	24	1815
6	5	30	1452
7	4	28	1555
7	5	35	1244
7	6	42	1037

Regularity in Planting is hardly attainable unless the *pits for planting* be opened at measured distances. This can either be done (as is usual in France and Germany) by measuring and plainly marking in each compartment the starting-points and finishing-points of the equidistant lines by means of a tagged cord, a measuring-tape, or a pole of the required length, and then in similar manner laying out the distances from plant to plant in the lines. Where great regularity is desirable, the lines and pit-places should all be marked off and pegged out for the workmen; but otherwise it is sufficient to stake off the planting-lines in sections well marked with a pole and a wisp of grass, or similar marks. Thus if there are ten planters, and the distance between lines is 4 ft., then each section must be 40 ft. broad. Within these sections each workman should keep his proper distance, from line to line and plant to plant, with a stick of the required size (4, $4\frac{1}{4}$, $4\frac{1}{2}$ ft., as the case may be, for planting in squares). Otherwise, if the planters be left to simply judge the distance by stepping, irregularity is almost bound to result, so that in place of having a regular distance of 4×4 ft. all over, as may perhaps be intended, one finds (when too late to be remedied) that some parts have been planted much too wide and others much too close. But if the leading man among the planters keep well to the guiding-line from pole to pole, any irregularity is confined to one section, and a fair start can again be made in the next section.

Wherever variation in the soil and situation renders close planting desirable, the object is much better attained by using a stick of the required length than by trusting to the eye.

In *notching* at 3 ft. the spacing may be much more safely left to the eye than in pit-planting; but even here the use of a measuring-stick is best.

In either case, after the initial and the final points of sections have been marked at the sides of the compartment for pit-opening or planting, the work is begun. The usual practice in Britain is for one of the more experienced hands to commence on the left-hand side, starting from the first mark, and working along the line to the mark on the opposite side; and all the other planters take their distance from him. As soon as he has opened one pit (or planted one plant), the man next him begins, and so on. Thus, if there are ten men (each assisted by a boy when planting), the first nine will have respectively opened nine pits or planted nine plants by the time the tenth man has begun work. As soon as the end of the compartment is reached, the line of pit-openers or planters wheels round and works on the backward drift along the next marked-off stretch of the compartment, each labourer without delay recommencing on his own proper line as soon as he reaches the end of the first stretch (No. 1 taking the eleventh line, No. 2 the twelfth, &c.)

If all the men are to start work on the line at once in opening pits, it is then necessary that they should be so placed that the quickest and most experienced planter is *at the extreme left* to keep the main line and guide the others, and that these others should be ranged with the best man always to the left-hand side, because no planter can go on with his work until his left-hand neighbour has marked his pit. When the pits have been previously opened or pegged out, all the planters may begin work at once in lines, or each man and boy may have so many lines (say a quarter of an acre or more, according to the class of work) allotted to him as the day's task.

When the plants are forwarded from a home nursery, fresh supplies should be sent once a-day, or more frequently if needed, well packed in convenient bundles in a covered cart. As each bundle of plants is opened, the bundles of fifty should be distributed (see p. 384) every quarter to half-hour, as that will just about keep the men supplied in notching and pit-planting respectively. *Keeping the roots moist and cool is a point of primary importance, to prevent the root-hairs and suction-roots becoming shrivelled and dried up.*

To ensure good work, it is of course necessary that the labourers should be supervised by the forester or by a competent foreman, more especially if the pit-opening or planting be done by piece-work. Ordinarily, it is best to do such work as trenching and pit-digging by contract; but planting is best done with daily labour. Bad work in the former can be seen at once, but faults of carelessness or the scamping of work in planting are hidden from sight, though proper treatment as to position and depth of the roots in the soil is essential for the success of any plantation.

If the plantation is intended to be a stencilled mixture, the planters must of course be properly instructed and have the different kinds of plants given out to them. But if, as is usually preferable, the mixture is in patches, these should be marked off and planted by themselves.

The way in which it was thought planting could best be done about twenty to fifty years ago was thus described by Brown (*The Forester*, amended and abbreviated):—

After the different classes of soil have been marked off into compartments for planting, the plants required should be brought from the nursery and sheughed or laid temporarily in the soil in their respective compartments. If the nursery be too far off to have the plants transported in small lots as required, great care should be taken to see that all their roots should be covered during the journey, to prevent the air from drying them. As soon as the cart arrives, a deep dry part of the ground must be chosen for laying them in cautiously, care being taken not to employ too many hands on the work at once. Only as many plants need be brought forward at one time as may be wanted for planting one or two compartments; for if they are all lifted at once from the nursery and sheughed on the area to be planted, then should bad weather come on they may have to lie so long as to get injured in the sheugh.

If sheughing can be avoided, that is of course best. But if it be really necessary (as in getting plants from nurserymen at a great distance), a trench should be dug deep enough to hold the roots easily; and the turf and earth taken out should be put upon what is meant to be the outside. If the broad-leaved plants are to be put in first, this may be done without loosening the bundles of plants, as they keep good though lying thus some time in the ground; but the bundles of Conifers should be opened out and the plants spread not more than 2 inches thick on the side of the trench. When the whole trench is filled with plants, whether deciduous or coniferous, the finest of the earth from the next trench should be put on their roots so that no air-spaces may be left, and sufficient soil should be thrown in to cover the roots of all the plants laid in, as well as to make another trench large enough for another row. The roots being sufficiently covered, the whole should be lightly trodden down to keep out frost. And so on for trench after trench, till all the plants are bedded. Many planters sheugh the plants in a casual way, but they should be as carefully placed as if they were to remain there for months. Should frost set in, and snow perhaps follow, the plants may have to lie for a couple of weeks or longer. When the weather breaks a large proportion of casually treated plants will probably die, so that planting would become either unsatisfactory or very expensive.

The number of men required for planting must next be considered. It is better to have the work done properly by a few good hands than to collect many labourers, who have perhaps never planted before, and who may really care little how they do the work so long as they receive their wages.[1]

Say, for example, that the planting of one block of 160 acres (suitably divided by roads, drives, and paths into convenient compartments) is to begin and be, if possible, completed during February, so as to set men free for further planting in March and April.

[1] This is just where, and why, useful instruments like Heyer's cylindrical spade (Fig. 35) are of value. With such tools even ignorant hands—men, women, or children—can do the work just about as well as more intelligent workmen. To make a hole in the ground with an instrument, for a boy to fill up with a ball of earth practically of the same size, requires no knowledge that cannot be acquired thoroughly in a few minutes, even by a very ignorant person.

Nominally this allows of four weeks, but as it is more than likely that some of the time will consist of bad weather, it will perhaps be better to calculate only 18 instead of 24 working days. If the plants are to be notched at $3\frac{1}{2} \times 3\frac{1}{2}$ ft. (3556 per acre), it may be reckoned that a man and boy in a short winter day of five hours (working from 8 A.M. to 4 P.M., with one hour's interval) should notch 900 to 1000 plants, doing the work well. If a man be hurried, he cannot plant well: the forester should therefore only try to get a fair day's work, and it will then be much better done than otherwise. But in February they can work from 7 A.M. till 5 P.M.; and each man and boy will be able, if experienced, to notch 1200 to 1300. Inexperienced hands will, however, plant nothing like that number. Taking 1250 plants as the average day's work, then the notching of $(3556 \times 160 = 568{,}960) \div 1250 = 474$ days' work of a man and a boy, and a gang of 26 men and 26 boys will be needed to accomplish it in 18 working days. Supervision is, of course, easier the smaller the gang of men is; and it is well to spread planting over a longer time, if convenient, than to employ a large gang in getting it done quickly.

If the work is to be pit-planting, it will, of course, take much longer. Say a man and boy can pit 500 plants a-day, then no less than 63 men and 63 boys would be required to complete it within the 18 working days, and it would need at least 2 foremen to supervise them properly.

When the men begin work the forester should note the number of plants put in during the first day or two, and compare the actual work with his previous estimate, so that he may know if more men are required to complete the work in the given time.

When the date comes for beginning, the forester should be early on the ground to arrange work for the day. He should have three or four poles, such as farmers use for measuring off furrows; and while the men are collecting, he should measure off the proper breadth for the men to begin on, putting up a pole as a guide for the innermost man to go by in the act of planting; and in like manner the whole length of the ground should be marked off by poles before the men commence.

He should next see that each boy has a strong apron, or a well-protected basket, for holding the plants and protecting them from the air while he carries them about and takes out one at a time with his right hand. He should also examine the men's spades. For notching, a half-worn garden-spade with a blade 8 to 9 inches long is better than a new spade, as one can work much more rapidly with it. Otherwise the **planting-spade**, made small in the blade, and with the iron part clasping the wooden handle made stronger than in the common garden-spade, to resist the stronger pressure sometimes put upon the handle in the act of notching upon the tough turf, is a good implement.

The sheughed plants should next be put in charge of a man whose duty will be to give out the plants as required, the plants being taken to the planters by boys specially instructed how to protect the roots from the air, and given to them in bunches of about fifty every quarter of an hour (for notching), so that work should never be delayed through want of plants.

When the men and the boys carrying the plants are all ranged in line along the edge of the compartment, and each man has been given his breadth to plant, the forester should show them how he wishes the planting to be done, how the proper distance is to be kept between each two consecutive plants, and how the plant is to be put into the notch or the pit and firmed in.

As work proceeds, the forester should see that it is done according to the directions given. He will, of course, have to pay most attention to new hands, but should go backwards and forwards among the planters, minutely examining the work, and seeing that it is being properly done. Faults ought to be checked at once; and if they be persisted in, it is better to pay off the man and boy in question than to run the risk of having the work badly done. Every notch and pit should be properly closed to prevent lodgment of water and danger from frost.

Before the planters arrive at the poles set to mark the lines on the other side of the compartment, the forester should measure off another breadth, upon which the men fall in and plant another breadth of land, bringing them back to where they began first of all. Each time a new breadth is being started, he should be there to see the men fall into their proper places, until, after crossing and recrossing, the whole compartment has been planted.

On moist land, whenever the day is wet, the men should not be allowed to work after the ground is saturated with rain. As soon as the earth does not set properly round the roots of the plants, orders should be given to drop work.

The Cost of Planting is now very much greater than it used to be. From 30s. to 40s. per acre, it has risen to from £4 to £6 in many cases, and often even to from £6 to £8 per acre. Plants and labour now cost about twice as much as formerly; and rabbits are also so destructive and so universal throughout Great Britain, that it is usually necessary to fence plantations against this pest with expensive wire-netting, which may add considerably to the cost of planting. This heavy extra charge per acre for protection against rabbits (which should be debited to *game* and not to the woodlands) in many cases swallows up whatever profit might otherwise be obtainable from growing timber. Indeed, unless where rabbits can be kept down, as they used to be, no landowner will, I think, be well-advised to plant extensively with a view to profit.

The price of manual labour of course varies locally, but as a rough average the notching of seedlings can be contracted for at from 2s. to 3s. per 1000; while for pit planting, the opening of pits of 10 to 16 in. broad and 9 to 12 in. deep costs from 1s. 6d. to 2s. per 100, and planting other 6d. to 1s. per 100. For plantations made on a large scale (at 4 × 4 ft.) the opening of the pits and the setting of the plants should not cost more than about 50s. an acre.

So far as generalities apply, Conifers are cheaper to plant than broad-leaved trees. The notching of Conifer seedlings is of course the cheapest of all methods, and next to that comes planting with small balls of earth (Heyer's cylindrical spade), while pit-planting and mound-planting are the dearest of all; and the cost increases with the size of the plants used and the number planted per acre.

If the land requires little or no draining or special clearing, and notching can be done at 3 × 3 ft. (4840 per acre, or say 5000 ordered) with young Conifers costing on the average 9s. per 1000 (including transport and delivery), then a man and a boy should be able to plant about a quarter acre a-day in early autumn or late spring, and the cost would then be, *exclusive of draining, clearing weeds, fencing, rabbit-wiring, or filling blanks*, per acre—

5000 plants, at an average of 9s. per 1000, delivered on spot .	£2	5	0
Notching plants, four days of a man and a boy at 2s. 6d. and 1s. 3d.	0	15	0
Cost for plants and planting only .	£3	0	0

This may be taken as about the minimum cost at which it is now possible to plant, if the plants have to be purchased from a nursery.

But it will seldom be found possible to plant at anything like so cheap a rate as that. The class of land which it may be desired to plant will probably often need drainage, clearance of heather and furze, trenching, or other soil-preparation, which all mean additional cost; and a stronger and dearer class of plant, with a more expensive method of planting, will usually also be necessary. Taking the general average of unimproved waste land suitable for planting, the following rough estimate is not likely to be far wrong for the planting of Conifers, mostly of Scots Pine, Spruce, Larch, Douglas Fir, and Silver Fir in mixed woods, where each kind of tree is planted in patches specially suited to it—while it will also cover the cost of planting Oak, Ash, Elm, Maple, Sycamore, and Beech, or Tree-Willows and Poplars, on better classes of land where less drainage but more of other expense is incurred :—

Average cost per acre of Pit-Planting on Waste Land, with sturdy transplants about 1½ ft. high—

	Per acre.
Draining and fencing (*not* including rabbit-wiring); cutting and burning furze, heather, &c.; and exterminating rabbits . . .	£1 0 0
Cost of 3000 plants (for planting at 4 × 4 ft. = 2722 per acre, or say 3000 ordered) at an average of 20s. per 1000, including transport and delivery	3 0 0
Making holes (pits) in autumn, and planting in spring . . .	2 10 0
Total first cost of planting	£6 10 0
Add beating up blanks, and weeding and protecting during first two years	0 10 0
Total cost of plantation before it can become properly established	£7 0 0

This estimate presumes that the plants are purchased from nurseries; but if planting be undertaken systematically on any very large scale, with plants grown in home-nurseries, the first planting could probably be done at less than £6, 10s. an acre. This estimate does not include any allowance for wire-fencing against rabbits, which, at 6d. per running-yard, would involve a further charge, varying in its amount per acre according to the size and shape of the plantation (see vol. ii., Part IV., chap. i., concerning *Fencing*), but often large enough to make it very doubtful that planting could then be profitable. If pitting be done at 4¼, 4½, 4¾, or 5 ft. apart, the total cost is not likely to be much decreased, because both holes and plants have then to be larger and dearer on land of which the actual growing value is probably only from 1s. to 2s. 6d. a-year per acre, and the fee-simple, at twenty years' purchase, only from £1 to £2, 10s. per acre.

Coppices will seldom now be planted in Britain except in the form of *Game-coverts*, *Osier-holts*, or *Alder-* and *Ash-groves*.

For planting **Game-coverts** both hardwoods and softwoods are used, the plants often being truncated just above the roots to make them throw out numerous shoots at once. A sprinkling of shrubs like Privet and Rhododendron is desirable, and a few Douglas Fir, Spruce, or Silver Fir here and there, either as individual plants or in small patches, make a good dry shelter.[1]

Osier-holts for growing rods for basket-making may be planted in rows up to 24 × 12 in. (*i.e.*, 2 sq. ft. individual growing-space, and 21,780 plants per acre), while stronger withes for crates and hoops are produced up to about 30 × 18 in. (*i.e.*, 3¾ sq. ft. individual growing-space, and 11,616 plants per acre).

[1] This is not Sylviculture or forestry for profit, but specifically Game Preservation combined with Arboriculture. Special details from the latter point of view will be found in chap. vii., p. 477.

Planting usually takes place in rows, at a distance which depends mainly on the period of rotation. For the finer species of Willows, with annual rotation, the slips should be put out in rows about 20 in. apart, and at a distance of 6 to 8 in. in the lines (about 40,000 to 45,000 per acre); but for the coarser species, to be worked with a rotation of two years, rows 30 in. apart, with the slips at 12 to 15 in. apart in the lines, give ample density (about 14,500 to 17,500 per acre). Where several species are to be cultivated, they should be kept apart in different beds, as the less vigorous are otherwise interfered with in development by the species of more energetic growth (*British Forest Trees*, p. 332).

New plantations should be made with slips that have stood for one year in the nursery-lines, because they produce a strong crop one year earlier than if the slips are planted at once on the Osier-beds.

The German method is to plant 12-in. slips of 1- to 4-year-old wood at 20×4 in. (*i.e.*, $\frac{5}{9}$ of a sq. foot, and 78,408 plants per acre) upright in beds trenched to a depth of 20 in.; and preference is given to *S. viminalis*, *S. amygdalina*, and the hybrid *S. viminalis* × *purpurea*. The method adopted in the Fen districts (Board of Agriculture Leaflet, No. 36—*Cultivation of Osiers*) is as follows :—

Planting should be done in February or March. The sets are cut from wood of two years' growth: they should be 16 or 18 in. long, and about 10 in. of the set should be in the ground. The sites selected are deep, rich, moist alluvium, and the land is thoroughly cleaned and summer-fallowed, then dug or ploughed in autumn to 14-16 in. deep. A newly-planted holt will, under very favourable circumstances, mature in three years, but four or five years are usually required before it is in full bearing. If well planted and tended it will remain in good condition for ten to fifteen years, according to the kind of Osier and the nature of the soil, and the method and rotation of cropping.

The Osiers usually grown in the Fen district are known by local names. The favourite sorts are—

Salix triandra, known locally as *Glibskins* (in some situations particularly liable to "scab"), *Black Mauls* (small, but hard and tough, and consequently valuable), *Green Sucklings* (giving a heavy crop, but not liked by the basket-maker), and *Black Hollanders.*

S. purpurea, *Welsh Osier* (which, having a very bitter rind, disagreeable to all animals, is planted along the edges of holts).

S. decipiens, *Mottled Spaniard.*

S. viminalis, *Cane Osier.*

Alder-groves require to be formed with good strong transplants, owing to the rank growth of grass they generally have to contend against. On the whole, 2-year-2 transplants give the best results.

As a rule, the transplants are put in without earth attached to the roots, except on wet soil, where the balls of earth enable them to establish themselves sooner, and where also the larger assortments of the four- to five-year-old transplants are generally used. The operation of planting is simple, notching being frequently adopted on moist soil, but tumping or planting on mounds has often to be resorted to on wet situations. Close planting of the quick-growing Alder is out of place, and the plants should not be put out nearer than $4\frac{1}{2}$ or 6 ft. apart, or in rows of 5×7 ft. The time of planting depends very much on the soil. Where mounds or beds have been previously prepared, the putting out of the plants may take place in the spring, though as a rule this operation is performed in autumn, when there is less moisture in the soil; but when this is even too soft, the coming of the first frost has to be awaited. Plantations can also be made in the latter part of summer, when least moisture is present in the ground, but the transplants must then have balls of earth attached to the roots, and this increases the cost considerably (*British Forest Trees*, p. 234).

Forming Oak-woods by planting is still occasionally practised on good classes of land, although the cultivation of the Oak in any form—highwood, copse-wood, or coppice—is never again likely to assume the national importance that natural regeneration by enclosure, dibbling of acorns, and planting of transplants once had.

Wherever **Oak coppice-woods** are to be formed in localities prone to rank growth of grass, planting has undoubted advantages over sowing; and in order to stimulate the quicker growth of shoots, the transplants used should be at least three-year-old. As soon as the roots seem to have established themselves, the stem may be removed close to the ground. A preference is, however, given to the use of four-year-old transplants truncated close to the roots, which are then planted out rather deep in the soil. Transplants thus cut back yield a thicker growth of shoots (*British Forest Trees*, p. 211).

When planting of Oak was, during the first half of the nineteenth century, much more general than now, the usual method was of course to put out transplants in pits; but a curious method of truncating the plants and planting the roots, then allowing only one of the coppice-shoots to grow up, was sometimes practised on high-lying districts planted with transplants from a sheltered nursery. On being cut over, the plants would usually send up several shoots; and if all were removed but one, its growth would in two years be as great as that attained by the unmutilated plant in three or four years.

Such mutilation of plants, except for coppice, is a direct interference with the vitality of the tree, which is certain to show its influence in the later stages of development. Oak highwoods raised from stool-shoots can never attain the same dimensions as crops raised directly from seed; the former begin to flag far earlier in annual increment.—This peculiar method (well enough suited for coppice, but not for highwoods) was thus described by Brown (*The Forester*, abbreviated):—

Some foresters cut back the plants, immediately on receiving them, to within 3 in. of the roots, and then plant them in the prepared pits; and they assert that they thus gain young shoots a year sooner than if they had allowed the plants to remain for one year in the ground previous to being cut over in the usual way. But the shoots produced are weak during the first season; and no vigorous growth is made till the second year. The plants require a full year to establish their roots. Wood made during that year seldom matures, and is apt to be nipped by the first winter frost. But when the young plants are allowed to establish themselves first, and are only cut back a year after being planted, they make stronger shoots in that one season than plants of the same class cut at the time of planting and having two years' growth of shoots.

But even this modification of the system is objectionable, and should only be resorted to if the plants begin to die off after planting.

Pit-planting is the usual method of growing Oak and all other kinds of hardwoods. On indifferent soil or on an exposed situation, the plants may sometimes find difficulty in establishing themselves, in which case the normal balance between imbibition and transpiration may be so much disturbed that the stem dies off; but if the root-system still remain active, moribund plants can be cut back to the root, and young shoots will usually be sent up to take the place of the dead stem.

Oak plantations are seldom likely to be profitable on exposed situations. But while there was a great national demand for Oak early in the last century, such were often formed, Larch or Pine being scattered among the Oaks as "nurses,"—a plan that still obtains throughout Britain with regard to Oak and other hardwood plantations.

In such cases it should always be borne in mind that the main crop consists of the Oak and other hardwoods ; and whenever the time comes for removing the "nurses," they should be cut out immediately. Their task as "nurses" is generally completed within about five or six to eight or ten years at most, and they should then be cut out at once, especially in the case of otherwise pure Oak-woods, because Oak (and next to it Elm) is less tolerant than other hardwoods of anything interfering with its lateral expansion after once it has fairly established itself in the soil. To let the Larch or Pine stand for two or three years after they are no longer required to protect the hardwoods against heat, drought, and cold, in the hope of getting a better price for them as early thinnings, is to deliberately prejudice the ultimate development and value of the permanent crop.

Soil that is good enough to plant with a crop of Oak or other hardwoods is usually far too rich to produce sound resinous durable Pine. When the soil is too rich, Pine timber is soft, spongy, and unable to resist either fungous infection or insect attacks.

In sheltered situations, where the soil is suitable for Oak and other hardwoods, an admixture of Beech improves and protects the soil. The distance at which such plantations may best be made has been previously dealt with (p. 406).

When a landowner thinks of forming a pure Oak-wood, he should first consider whether young Oak thinnings will sell to advantage, and if they will pay better than other wood of the same age. If young Oak spoke-wood 5 to 8 in. diameter sells well, it may be advisable to plant Oak at 8 ft. apart, and to fill up with Larch and Beech at about 4×4 ft. By the time the Larch are gradually cleared out, the Oak and Beech will form good canopy, and the crop can then be tended with due regard to the former (Brown).

German experience regarding the best methods of planting Oak-woods may be summarised as follows (*British Forest Trees*, p. 209) :—

Planting of Oak of all sizes up to 7 or 8 ft. can quite well be carried out without balls of earth around the roots, but with the older plants some mutilation of the tap-root can hardly be avoided, which may later on lead to hollowness of the stem in the mature tree : at any rate, there can be no doubt that, when the tap-root has been reduced to any considerable extent, the young plant does not regain a healthy appearance until its underground nutritive organs have recovered from the injuries inflicted. On the other hand, planting with an undiminished tap-root is an expensive method, especially on hilly or stony soil, where the pricking out of small seedlings with iron pegs or notching tools is not as feasible as on deep low-lying soil.

One- and two-year-old seedlings from self-sown woods or seed-beds are usually notched in thickly on the lighter varieties of soil, no shortening of the tap-root being then necessary ; but for all seedlings and transplants beyond that age, some trimming of both the ascending and the descending axes is necessary. Very good results can frequently be obtained by the use of two- to three-year-old transplants in rows of 4 to 5 ft. $\times$ 3 ft. When older transplants are desirable, the distances at which they are put out vary from about 4 ft. $\times$ 4 ft. to 10 ft. $\times$ 10 ft., or the equivalent growing-spaces if in rows, as the initial cost rapidly increases with the size of the transplants. It is, in fact, this question of cost that at times determines in favour of sowing ; for quicker, and on the whole more reliable, results are undoubtedly attained by planting than by sowing.

Planting is usually carried out in spring, but somewhat later than in the case of the Beech, as the Oak is about a fortnight later in breaking into leaf. As, owing to the tap-root, transplants are seldom put out with balls of earth attached, care must be taken to preserve the rootlets from becoming dried up. The transplants are put somewhat deeper in the soil than they have stood in the nursery, especially in loose porous soil, as experience has shown that the soil has generally a tendency to sink in setting. Where pits are prepared for single plants, or patches are trenched for groups or knots, the earth-work should be carried out in autumn, so as to give it full opportunity of setting on the surface before the transplants are put out in the following spring. The use of older transplants of 4 to 6 or 8 ft. in height is generally now confined to situations where it is necessary to give the Oak a good advantage over the Beech, and in localities where it is exposed to danger from cattle or deer.

Ash, Maple, Sycamore, and Elm are seldom planted except in groups in new highwoods, where they are intended to occur merely as numerically subordinate species. They find the best conditions for growth on suitable places where Beech-woods are being regenerated (see details in Part II., pp. 127-142).

Planting of Ash, either as naked seedlings or transplants of almost any size, is easy, as the plants establish themselves readily when put out. In moist frosty localities planting succeeds best when carried out under shelter, as for example under Alder-poles a few years before their clearance, so that the young Ash may have a few years' growth in advance of the future flush of quick-growing coppice-shoots; and either healthy seedlings, or transplants from the nursery, are then used. Although the Ash can stand trimming of rootlets and twigs better than most other species, this is seldom necessary, owing to the simplicity of planting in the loose soft soil. The method adopted may either be notching or pit-planting.

Planting of Maple and Sycamore should be done in spring, and somewhat late when frosts are to be feared, even though the buds may be beginning to break into leaf. Trimming of seedlings or transplants should usually be unnecessary, and ought not to be done if avoidable, as both species are somewhat deficient in recuperative power, and rather susceptible to damage, especially of the rootlets.

Planting of Elm is easy, and the choice extends from yearling seedlings to four- or five-year-old transplants, a preference being generally given to two- or three-year-old transplants, to obviate danger from rank growth of grass. Reproduction of Elms can also take place by layering, as is extensively practised in Holland. . . . Layering and planting can best be done in autumn, from the middle of October till the middle of November, as the movement of the sap begins early in spring. As in the case of Maple and Sycamore, planting may be either notching and replacement of the sod or pit-planting with the hand, either operation being easy and without any special peculiarities. (*British Forest Trees*, pp. 250, 261, 271.)

Planting Waste Land.—The waste lands in the British Isles may be roughly divided into four different main classes—(1) *Rough Mountain Pasture*, and poor deteriorated land thrown out of agricultural occupation, the latter being, unfortunately, especially abundant in Ireland; (2) *Moorland, Peat-bogs, and Moss-hags*, formed above impervious clay or moorpan; (3) *Low-lying Marshes and Swampy Land;* and (4) *Sandy Stretches near the Coast.* But it is only on land of the first two classes that profitable sites for large plantations need be sought, as swampy land costs a great deal to drain, and (being usually fertile enough) thorough drainage makes it suitable for agricultural occupation, while sandy stretches have now a special value as golf-links.

The better class of waste land is usually covered with furze or broom, or with a mixture of furze and bracken, while the poorer stretches of barren mountain-land and the shallow-soiled exposed uplands are generally overgrown with heather (ling) chiefly. The growth of grass is there never strong enough to interfere with planting. In the peat-bogs and their immediate vicinity, bell-heather and the common ling usually overgrow the surface-soil, and it is only the "cut-away" parts of such tracts that can be planted at present with any fair chance of profit. But these are, at the same time, just the parts that can easily be brought under profitable agricultural occupation.

Shelter and **Drainage**, natural or artificial, are the two most essential conditions for planting with profit on waste land in Britain. If there be no natural shelter on land otherwise suitable in soil and altitude, artificial protection must first of all be formed by planting shelter-belts. Land on which either **furze** or **broom** grows luxuriantly is certain to produce good crops of mixed Conifers, that ought to prove a profitable investment of capital. Such land is generally loamy and has a good natural drainage. Furze or broom, unless of very strong growth, if cut over with the switch-bill in June or early in July, *after the spring flowering, but before the seed-pods ripen*, and then burned in August or early in September, will usually either get killed outright or be greatly checked in growth for some time. Then the planting-holes can be opened in autumn for the soil to weather throughout the winter, and the planting can take place in spring with the best chance of success. But if the growth be so strong that grubbing up the roots is necessary, this should be done in strips, and the rubbish burned when dry enough.

Whortleberry (blaeberry) gives little trouble and can easily be cut back, but where the soil-covering is chiefly **heather**, this should be burned either one or two years before planting. Sporadic growth of Birch, Aspen, Alder, Mountain Ash, or Sallow, in moist spots near rivulets, may often have to be grubbed up, otherwise their strong flush of shoots and suckers may interfere with the young plants if they are cut back. But it is often best to plant slips of Willow or Poplar thickly there and leave them as small patches.

The wastes on which **bracken** forms the characteristic soil-covering are usually not of such good quality as the areas covered with furze or broom. Still, they form good plantable tracts; and if the bracken be cut in June *before the fronds expand*, the strength of their growth remains diminished for the next three or four years, by which time young plantations should have established themselves and outgrown danger from the fern.

Except to the comparatively small extent to which the **peat-bogs** have been cut away, there is not (even with previous drainage) much chance of planting with profit on land of this class; because, even with expensive drainage and ditching deep enough to break through the stiff layer of clay or the thin impervious moorpan, upon the presence of which the swampy moorland condition depends, timber crops (even of Scots or Weymouth Pine) do not thrive unless their roots can soon get into direct contact with the mineral soil. And, in any case, this class of land, usually far from any favourable market for thinnings and mature timber, is not that which is at all likely to receive the first attention in any large scheme of planting with a view to profit.

The class of waste land most likely to be plantable with profit is that forming large compact areas which, in addition to suitable soil, elevation, and aspect, are within fairly easy reach of places likely to prove good centres for the disposal of small and large timber in the future.

To have any fair chance of being profitable, the planting of waste land should only be done in large compact blocks. Timber crops grow better in large masses than in small woods; there is better shelter from wind; the circulation of soil-moisture is more equable; there is economy in the first cost of outer boundaries and fencing, and annually in supervision, for one forester can far more easily supervise four or five compact blocks aggregating 2000 to 3000 acres than he can exercise proper supervision over half of that acreage if scattered about in smaller blocks of 100 or 150 acres.

In planting on mountainous tracts 1000 ft. or more in elevation, the plantations should always be larger than on lower-lying tracts. Unless planted in large masses to afford mutual shelter, the timber crops fail to attain any considerable value. As a rule, the higher the site, the larger the plantation ought to be to secure the advantages of artificial shelter in proportion as natural shelter is wanting. Inattention to this point has been one cause why many of the existing woods in mountainous districts have proved less profitable than they otherwise might have been,—though absence of favourable opportunities for selling the wood grown has been far more felt. In the Highlands of Scotland and many parts of Northern England small plantations may be found 1500 ft. above sea-level, stunted and almost worthless, either for shelter or for timber. Had such plantations extended to 300 or 400 acres, their crops would probably have been much more valuable in every respect (*The Forester*).

For mountain planting, with Scots Pine chiefly, but with other Conifers intermixed on suitable soil, strong wiry plants, grown on land of only average quality, should be used. Plants from sheltered nurseries with rich soil never do well. If the nursery soil be much superior to the land to be planted, then, owing to the greater difficulty in obtaining the food-supply that they have hitherto been accustomed to, the plants wilt for a long time before establishing themselves. But if it be inferior in quality, then their constitutional vitality is low, and they are naturally slow in establishing themselves after removal from the nursery.

1. **Rough Mountain Pasture.**—Wherever large blocks of moorland waste are intended to be planted, either by the State or by private landowners, the work should not be taken in hand until a simple, clear, and definite working-plan for drainage[1] and planting has been well considered and adopted for the next ten, fifteen, or twenty years. Such a plan can be modified at any time if circumstances make amendment desirable; but there ought to be systematic regularity and **method** about the whole business.

It is not sufficient merely to arrange for planting the kinds of trees likely to thrive on the given soil and situation; one must also look ahead to the time when these plantations become mature timber, and must consider how they can then be cleared without running needless risk of damage from wind and from insects. This looking ahead to the future fall is a very important point, which seems usually to have been hitherto quite neglected when making large plantations in Great Britain and Ireland.

Except in sheltered valleys, it will generally, on waste lands throughout Britain, be necessary to provide artificial shelter, by means of planting shelter-belts in advance, for the protection of the young timber crops. On the open and wind-swept waste lands throughout the British Isles, it will seldom be found that large compact areas will be plantable with profit without artificial

[1] For details concerning *Woodland Drainage* see p. 316.

shelter of this sort being provided to a greater or less extent; and on extensive stretches of hill-slopes, mainly with southern exposure, wind-breaks of this sort are an absolute necessity.

When it has been decided to plant any extensive area of waste land, its boundaries will have to be fenced and a network of main and subsidiary roads projected and marked off in the manner most convenient for the transport of the future thinnings and the mature timber crop—though, of course, there is no necessity for metalling the roads in the meantime. This can easily be done with the aid of the contour lines on the large-scale maps of the Ordnance Survey. This road-system should be so planned that the whole area can be divided into main sections of about 440 yards square (40 acres), subdivided, if convenient, by narrower roads (220 yards apart), into 10-acre compartments,[1] and having one side at right angles to the most dangerous prevailing wind, generally the S.W.

Shelter-belts should next be formed to a width of, say, about 20 to 30 yards along the windward edge of each such main section, if the planting of the whole area is intended to be accomplished within ten years,—or along the windward edge of each alternate section, if it be desired to extend the planting over twenty years,—and the intervening stretch of about 410 yards (deduction being of course made for the road and the shelter-belt) can be marked off as the areas to be successively planted during each of the next ten years. *The planting of such shelter-belts (consisting of quick-growing thickly foliaged Pines and Firs), which will of course (except along the extreme windward edge) form part of the mature timber crops, should precede the planting of the rest of the area by at least five years, so as to allow the belts to establish themselves, and thus become able to afford substantial protection against cutting winds to the younger strips of plantation successively formed year by year to the leeward of them.* White Spruce is, on suitable soil, one of the best of trees to plant for giving shelter (see p. 241).

In the course of ten years (or of fifteen or twenty, as may be decided on), the planting (with Pines, Larch, Spruce, Douglas Fir, and Silver Fir chiefly) of each such section taken in hand will be completed. Looking forward to the harvesting of the mature timber crops forty, or fifty, or sixty years hence, the standing woods will best be protected against wind if the falls are made in just exactly the opposite direction—*i.e.*, if the falls are begun on the lee-side and are gradually continued directly in the teeth of the most dangerous wind.

That is to say, if the proper direction for the shelter-belts is to extend from N.W. to S.E. in order to offer their broad side to break the force of the S.W. wind, then the proper direction in which to make the annual falls of timber will be from N.E. to S.W., keeping the broad side of the fall running from N.W. to S.E.

It will be noted that (under the circumstances above supposed) while the

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[1] The mean dragging distance for poles and timber would then be $36\frac{2}{3}$ yards for $\frac{8}{9}$ of the area all round the edges, and $91\frac{1}{3}$ yards from near the centre for $\frac{1}{9}$ of the area, the central point being 110 yards from the outside. For further details see vol. ii., Part V., *Management of Woodlands.*

planting proceeds from S.W. to N.E., the falls of the mature timber take place from N.E. to S.W.,—or in other words that, in order to secure adequate protection against wind, one will have to cut down the youngest timber first of all. If one had old woods to deal with, it would be quite different, but where new plantations are concerned, this cannot be helped : some sacrifice is necessary, and the above slight sacrifice is the least that can be suggested. It need only mean—in the case of the planting being completed in ten years—either the cutting down of the youngest section five years before it is fully mature and of the oldest five years after it has really attained maturity, or else the leaving of the whole crop till the youngest portion is fully mature and then harvesting the oldest ten years later ; and in either case that means no great monetary loss in consequence.

In order to secure immunity, so far as possible, from damage by the Pine-weevil, apt to breed in the stumps of newly felled Conifer crops, it is best to try and arrange that falls of timber should not take place contiguously at less intervals than ten years (a system brought to high perfection in Saxony) ; but these matters are further dealt with in vol. ii., Part V.

2. **Moorland Peat-bogs** are generally accumulations of decayed moss resting on an impervious subsoil, usually of plastic clay and laden with stagnant water. Such soil, being cold, only produces stunted Pine, Birch, Aspen, Willow, and Alder, in its unreclaimed state, or merely bears an unproductive soil-covering of heath, heather, and rough grasses and bog-plants. Even after drainage, it usually remains dull and inert at first, but when it becomes more earthy it often forms a good woodland soil. This cold inertness is characteristic of the more purely humose "dripping peat," containing little inorganic matter.

Thorough drainage of such land by deep open trenches (about one-third deeper than they are intended to remain at permanently, to allow for subsidence) is necessary before planting can have any chance of succeeding. After the drains are opened the land should lie from twelve to eighteen months, so as to wash away the injurious acids (humic, geic, and ulmic acids, &c.), which require to be removed before planting can be successful.

In draining moss-land for planting, if the moss is not over 6 ft. deep, the trenches should be opened down to the subsoil, as only then can the land be made dry and suitable for growing trees. To drain moss-land properly for timber crops, the trenches should first be opened to the depth of from 5 to 6 ft. to make allowance for subsidence, and they should not be wider than 35 ft. apart. But if the moss be only about 3 ft. deep on the average, then, to secure an average depth of 4 ft. for the drains after the moss had subsided, they should be opened to the depth of 5 feet at first, allowing 1 ft. for subsidence (*The Forester*).

Experience in North Germany, on the other hand, has shown that—

Every moorland drainage-scheme should be begun early and continued gradually to its completion ; hence five or ten years, or even more, may be required, according to circumstances. The trenches can never be dug at once to the depth that they should eventually have. By gradual shrinkage the moor settles itself and gains in density ; whilst in other cases the trenches are closed up by the soft mossy soil, or nasty fissures are formed, or outlay of one sort or another is occasioned. As a rule, soft boggy moors should only be drained to a depth of 2 ft. to begin with (Burckhardt, *Säen und Pflanzen*, p. 561).

Unless drainage can be done cheaply so that the mineral soil can be soon reached, there is small chance of peat-bogs being plantable with profit, owing to the expense of draining and the cold nature of such land, where even Scots Pine and the hardiest of the other Conifers find difficulty in growing. The mere work of planting is usually cheap, as notching with the planting-stick (see Fig. 46) can be strongly recommended. But even well-drained hags of dripping peat will only grow Scots Pine intermixed with Birch, Aspen, and Spruce, the latter being introduced in anything like large numbers only in a sheltered situation. On the better classes of boggy and peaty land the White Willow and the two Black Poplars (Common and Canadian) sometimes do well; and in such case they may prove the most profitable trees that can there be grown. Weymouth Pine is also good.

In planting sandy moss-land, Poplar, Willow, Birch, and Alder may be grown at 4×4 ft. with Scots, Austrian, Corsican, and Cluster Pine, and Spruce and Silver Fir—all being, of course, mixed in groups in such proportions as may be considered suitable. Sometimes Oak and Ash can thrive on well-drained mossy soil resting upon clay; but in general such land is only suitable for conifers and softwoods.

As Burckhardt remarks (*op. cit.* p. 568)—

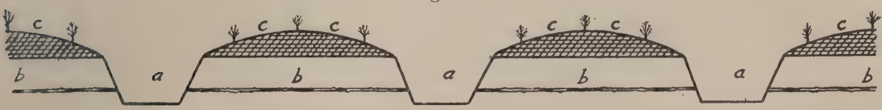
Mountain peat-bogs offer an especially difficult problem for solution; and the question whether or not they may be planted so as to yield profitable timber crops has not yet been satisfactorily and finally answered.

When, on moorland soils, we see almost all kinds of trees thriving in some places,—and especially when we see Oak, Birch, Spruce, Silver Fir, and Pine growing satisfactorily,—while in other places accommodating trees like Scots Pine and Birch only produce dwarfish crops, the explanation is in some cases to be sought in the varying nature of moorland soil, and in others in the method of treatment adopted; but both of these points require attention.

Where pits are opened, the plants should be of fairly large size; but if notched with the planting-stick, or if the situation be exposed, smaller plants are best. Poplar and Willow about 30 inches high, and Pine and Spruce from 6 to 9 inches, are usually big enough, unless there is a rank growth of weeds; and even then a cheap and simple method of notching on small mounds may still obviate any necessity for the more expensive pit-planting with larger plants.

Over Moorpan or Ironpan no tree is more responsive than Scots Pine to the benefits of soil-preparation. Throughout the great North German Plain, thousands of acres of moorpan are annually prepared for crops consisting mostly of Scots Pine, because the land is usually too poor for other trees to be mixed with it. During the last thirty years the steam-plough has been more and more extensively used in the work of breaking through the thin impervious layer of moorpan, generally found from 1 to 3 ft. below the surface. It has been found best to trench down to below the moorpan, usually forming quite a thin layer, and to spread the output on the beds between the trenches (Fig. 61). Where it lies at only 1 to 2 ft. deep, it can be broken through by horse-ploughs; but where it lies at 2 to $2\frac{1}{2}$ ft., **Fowler's Subsoil Ploughs,** worked by locomotives and iron hawsers, and making a furrow 24 in. broad and 30 in. deep, are the cheapest and most efficient way of breaking it up. They are extensively used on the waste lands in Hanover, Oldenburg, East Friesland, &c., being there obtainable on hire. The cost of thus steam-ploughing the whole land to about 30 in. varies from 24s. to 40s. an acre, according to the difficulty of transport and of procuring water (4000 gallons per diem being required; Gayer, *Waldbau*, 1889, p. 306); while Lorey

Fig. 61.



a, Trenches; *b*, Impervious layer of moorpan; *c*, Mounds between, topped with output from the trenches.

(*Waldbau*, p. 463) gives the cost of breaking through a thin shallow pan in strips with a common and a subsoil plough at 16s. to 32s. an acre. Where the moorpan is below 30 in. deep, the digging of trenches is the best way of preparing the soil, the spoil-earth being placed on the mounds between the trenches to weather during winter, and thus become fit for planting with Scots Pine in spring.

Hillsides and the Higher Uplands, from 500 to 1000 ft. elevation, are seldom (except in Ireland) classifiable as waste land, though planting may sometimes be more profitable than arable cultivation or pasturage. Their soil is mostly light and fairly good, and is well suited for the best class of Conifers. But large compact areas will seldom be obtainable; and planting in small blocks is seldom profitable, unless by way of indirect utility in sheltering fields. On such land Larch, Douglas Fir, and Weymouth Pine, the quickest-growing and most profitable Conifers, do well, as also other Pines, Spruce, and Silver Fir; while at lower positions the soil is often good enough for Oak, Ash, Elm, Maple, Sycamore, Beech,[1] and other broad-leaved trees.

All the better and more sheltered portions of such land may either be planted with sturdy transplants (about 2 ft. high) of Oak and Ash set 8, 9, or 10 ft. apart and filled up with Beech, Maple, and Sycamore at 4×4, $4\frac{1}{2} \times 4\frac{1}{2}$, or 5×5 ft. all over. Or, following the natural method, they may be mixed in small patches suited to differences in the soil, which has the advantage of utilising the soil more fully. The admixture of Larch, Douglas Fir, and Pine with Beech and Sycamore will produce finer timber than can be grown in woods consisting of Conifers only.

On land of this class there will often, unless it has recently been in arable cultivation, be a sprinkling of Hazel, Hawthorn, Blackthorn, Blackberry (Bramble), and Sweet-briar, which will have to be cut back with the switch-bill and then burned as rubbish before planting is begun; and the use of good big plants is

[1] On the Continent good results have often been attained on hillsides with deteriorated limy soil (such as are often to be seen on the Chiltern Hills and other parts of the Chalk-range in the south of England) by sowing lucerne and Beech-nuts at time of planting Austrian Pine, the lucerne being left to form *humus* and not cut for fodder.

necessary to contend against the strong growth of thistles, nettles, tall grasses, &c., which often spring up and need heavy weeding to check them till the plants get their leaders well out of danger. And the better the land, the stronger will be the growth of weeds. Pit-planting is usually needed here, even for Conifers; but on high ground, where the herbage is short, good strong naked plants may be notched, or a sod of turf may be thrown back and the plant notched into the little mound thus formed. If the soil-covering is of a dry nature, or can be easily switch-billed like broom, it is best to burn it to retard the growth of weeds; and at the same time this enriches the soil to a certain extent.

The Lower Uplands, under 500 ft. elevation, are seldom classifiable as true forest land. Where such is set apart for planting, however, mixed crops of broad-leaved trees may be formed, each kind of tree being put on the patch of soil best suited to it, or all the species may be intermixed individually, as the planter may desire (see p. 411). When "nurses" are needed for protection from late frosts, Larch, Pine, or Birch may be interspersed individually, and removed as soon as the danger is outgrown.

When good loamy land about 200 or 250 ft. in elevation has been prepared for planting, plants of large size are necessary, as the herbage usually grows very strong in summer and the ground becomes covered with St John's wort, raspberry, bramble, foxglove, &c. If hardwoods are to form the permanent crop, transplants of 2 to 3 ft. high may have to be used; while, if nurses are needed, Larch transplants of 2 to 2½ ft., or Pine about 12 in. high, will have to be used. But it may often be best to plant frost-holes entirely with Douglas Fir or Larch, unless the natural drainage of the soil is imperfect, when Ash, Willow, and Poplar may perhaps be most profitable.

Plantations near the Sea-coast seldom thrive, owing to the blasting winds from the sea. The trees most suitable for this class of planting include Sycamore, Maple, Beech, and Elm among broad-leaved trees, and Austrian, Corsican, Maritime or Cluster, and Banks' Pines among Conifers. Only sturdy plants need be planted; and those transplants have the best chance of success which have been already transplanted more than once in the nursery-beds, and have consequently a compact fibrous root-system. Plants which can be easily lifted by a large cylindrical spade, and replanted in holes of similar size and shape, have least disturbance to overcome in establishing themselves; but this presumes a fair degree of consistency in the soil. Poor, sandy, sea-coast land can seldom, if ever, in Britain be planted with profit.

Although Beech, Maple, Sycamore, and Elm all stand the sea-breeze well, yet on very light and mossy or poor and thin soil they find greater difficulty in establishing themselves than the far more accommodative Pines. Though the latter often grow well on poor sandy soil, they can hardly be expected to do so when they have at the same time to contend against the strong salt-laden sea-breeze.[1] If the hardwoods seem to languish much after planting, they may do better if cut back to the root and allowed to grow up as coppice. When once an outer **shelter-belt** of 20 to 30 yards wide, formed of such trees,

[1] See details about the Knockboy plantations on west coast of Ireland, *Introduction*, p. 100.

has fairly established itself, plantations may more easily be formed behind it of any kinds of trees suitable for the land, while agriculture is also greatly benefited by the protection given.

Besides the trees above-named, which will usually form the bulk of a shelter-belt, other trees may be mixed with them for arboricultural effect. Suitable trees include the Common, Evergreen, and Turkey Oak, Pear-tree, Dwarf Pine, Mountain-Ash, Service-tree, Huntingdon and Bedford Willow, Abele and Ontario Poplar, Yew, and Silver Fir. When these begin to grow up and get thin below, they may be underplanted with Sea-buckthorn, Holly, Rhododendrons, Laurels, Privet, Dogwood, Guelder-rose, Hawthorn, Scots-rose, Snowberry, Barberry, Broom, Furze, &c., because everything that helps to break the wind is of use.

Brown's recommendations for coast-planting, far too expensive except for purely arboricultural work, were to the following effect :—

Having lined off a belt of land, not less than 200 yards broad along the tract to be planted, it should be fenced, with a stone dyke if possible, on the side next the sea, whence the biting wind usually comes. This dyke should usually be about 6 ft. high ; but if stones for this purpose cannot be got conveniently, a turf dyke of about 4 ft. high may be erected and topped with a wire fence 3 ft. high, closely wattled with branches of Spruce or other obtainable tree or shrub, the object being to have a fence of about 7 ft. high to break the force of the sea-breeze and shelter the young trees planted inside. On headlands jutting out into the sea, the line of fence should take a bold convex bend in the same direction, thereby increasing the general width of the plantation. All wet parts should be drained, trenched, or otherwise prepared during the autumn, for planting work ought to be carried out in April, as experience has shown this to be the best time. Pits at a yard apart should be dug at least three months previous to planting (*The Forester*).

Barren Sand-Dunes of large extent are hardly to be found in Britain. And in any case the present passion for golf makes them pay, directly or indirectly, better as links than if planted. Any such stretches of light sand, easily blown about by wind, that it is desired to plant, may perhaps most effectually be wooded with Banks' and Corsican Pine ; and when once these are beginning to establish themselves, blanks may be filled with the more valuable Scots Pine. The Banks' Pine (see p. 217) does not grow to large size, but is of great use on poor, dry, sandy tracts as a first crop by improving the soil, and thus paving the way for something better thirty to forty years later.

On the Earl of Leicester's Norfolk estate interesting ornamental plantations have been made on the Holkham sandhills. Until the year 1850 these were rabbit-warrens. They extend about 3½ miles along the Norfolk coast, are from 5 to 25 chains wide, and are bounded by the German Ocean on the north, and on the south by rich pasture-land reclaimed from the sea, dating as far back as 1660, when the first enclosure was made. The sand is held by the marram (*Psamma arenaria*), a plant having a strong creeping perennial root, with many tubers at the joints about the size of a pea. It is planted and encouraged on the Norfolk coast to aid in fixing the sand against the action of the wind and tides, which it does in a remarkable manner ; and this marram, matweed, or bent grass is of such importance that there are severe laws to prohibit its being destroyed. The sea lyme-grass (*Elymus arenarius*), a strong, rough, glaucous plant, common on sandy shores, is also frequent here, and answers the same purpose as the bent in fixing the sand.

About fifty years ago small experiments were made with the Austrian, Corsican, and Scots Pine, protected from rabbits. No great amount of success was anticipated, as the soil was almost pure sand. By the end of the first year the plants had made shoots of 1 or 2 in., and seemed healthy; and in the second year they did so much better that it was decided to exterminate the rabbits and plant portions of the hills annually till the whole was under wood.

The east end of the hills, nearly 2 miles in length, which was only partly planted previous to 1865, is now a thriving wood, giving shelter to adjoining pasture, and considerably enhancing the beauty of the landscape; and the trees are doing much better than might have been expected.

In 1877 the plants had in many cases established themselves well, though the tops of the Corsican Pine were badly injured by the northerly winds and the blowing sand. The crests of the hills were about this time planted, principally with Austrian and Corsican Pine. On these establishing themselves, the Corsican Pine cut by the wind began to improve; and by 1882 a very decided improvement was noticeable. Since then the plantations have been considerably extended, the plants being mixed in the following proportions:—

Kind of Pine.	Proportion of Crop. Per cent.	Distance between Plants.
Corsican	50	planted 8 yards apart.
Austrian	25	" 5 to 7 "
Scots	20	" " "
Maritime	5	" " "

As the plantations were made for ornament and shelter, and not for profit, these distances gave plenty of room for lateral expansion. The Austrian and the Maritime Pine, planted at 5 to 7 yards apart on the higher and less sheltered situations fully exposed to every storm, are of course not so vigorous in growth as the more sheltered Corsican and Scots Pine.

In Germany there are large stretches of shifting sand, both along the coast and in the interior of the country; and this has to be fixed before it can be planted,—not so much for profitable growth of timber as for general economic reasons. First of all, the tracts to be dealt with are fenced with ditch-and-mound to keep out cattle. Then the sides of high drifts hollowed out by the wind and all deep clefts are sloped down gently, while the crests of dunes are pared down and levelled. After that, commencing at the windward side, the sand is either partially covered with turf in hollow squares, each with a piece also laid in the centre, or else covered with Pine branches, heather spray, furze, coarse grass, and seaweed. In either case it is best to lay the partial covering during wet weather, so as to keep the sand damp as long as possible. Formerly hurdles used to be erected to break the wind, and catch and hold the drifting sand, but now this method is seldom employed. Banks' and Scots Pine are then planted, either with balls of earth round the roots or naked plants with roots 5 to 7 in. long. On sea-coast dunes various sand-grasses (*Arundo arenaria*, *Elymus arenarius*, and *Carex arenaria*) are often sown or planted to bind the sand before planting with Pine (Lorey, *op. cit.*, p. 462).

The turf is cut about 6 in. square and 1½ deep, and laid in squares of about 40 in., and the growth of grass generally begins to spread during the first year. This method costs about 20s. to 30s. per acre. Planting is done with three- to four-year-old Pine in balls of earth, set 3 ft. apart, and put in rather deep, close to the edge of the piece of turf on the windward side. Planting costs from 16s. to 21s. per acre; and the whole operation usually comes to about 40s. to 50s. an acre.

In East Prussia, along the shores of the Baltic, large reclamations of this sort have been in progress for many years. Where no outer dune has been naturally formed along the edge near the sea, fences are erected to catch the sand driven in after being thrown up by the tides; and as a dune forms, the fence is moved up till the dune is about 35 ft. high, when it is planted with sand-grasses and the Creeping Willow (*Salix repens*) to bind it. Under the shelter of this outer dune the shifting dunes are then levelled, sloped off, and finally planted with Scots and Mugho Pine (*P. uncinata*).

The cost of planting sand-dunes in Germany varies as follows (*Forst- und Jagd-Kalender*):—

1. *Fixing sand* with hurdles about 3 ft. high—including cutting and cartage of brushwood, and making and placing of the hurdles, per running yard .	4d. to 9d.
	Day's work of a man.
2. *Planting with Sand-grasses*, 700-800 6- to 7-inch bundles being used per acre—	
(1) Hand-plucking the grasses and tying them in bundles, per 100 bundles	1·7-2·7
(2) Dressing and levelling the surface before planting, according to circumstances, per acre	14-26
(3) Planting the grasses in rows or in a network, per 100 bundles .	2·7-3·0
(4) Cartage of grasses for 9-10 miles, per 100 bundles . . .	3s. to 6s.
3. *Planting with Trees*—	
(1) Planting one- and two-year-old Pine on patches improved with loam, 6 plants being put on each patch at 3 × 3 ft., per acre .	90
(2) Ditto, but without putting loam on the patches, per acre . .	20
(3) Planting three- to seven-year-old Pine in balls of earth, at 3 × 3 ft., including carriage of plants, per acre	48
(4) Planting Alder and Birch, 5-8 ft. high, per acre . . .	36

In Northern Germany the strong perennial-rooted Everlasting-Pea (*Lathyrus sylvestris*) is largely cultivated throughout immense tracts of barren sandhills along the coast, where it is said to form a far better means of bringing these vast wastes under profitable and permanent cultivation than the planting of Pine. After private experiments had been carried out on a large scale for several years on sandhills where crops of Pine and Spruce had failed owing to the young trees being either smothered or uprooted by the ever-shifting sand, it was found that a flock of sheep could be kept on the *Lathyrus* fodder grown on the identical sandhills where, six years previously, not a blade of grass could be seen.

The most extensive and remarkable works of this class are the Maritime Pine plantations in the Departments of the *Landes* and *Gironde*. During storms enormous quantities of sand are thrown up all along the coast, and are blown up to the crest of the outer dune, then fall down the other side at an angle of about 45°. The base of this talus, therefore, constantly pushes forwards, sometimes advancing 15 and even 20 yards in a year. As these sandhills are sometimes over 250 ft. high, no obstacle can stop their onward progress — even villages being engulfed in their sands. Before the end of the eighteenth century these districts had become barren deserts, and the destruction caused by the sand had already been so great that measures were considered for trying to alter the state of affairs; but it was not till 1851 that a well-considered plan was begun to be acted on. Since then, over 157,800 acres have been planted with Maritime Pine; and besides greatly improving the general economic and agricultural condition of the district, this has created a new and important industry in timber and turpentine. The plan of operations adopted was as follows (Boppe et Jolyet, *Les Forêts*, p. 473):—

At about 60 to 90 yards back from the high-tide level, a paling of boards about 5 in. wide and about 1¼ in. thick, with spaces 1-1¼ in. between, is set deeply into the sand so as to project about 3½ ft. above it. After each tempest the sand, blown by the wind, heaps itself against the paling and trickles through the 1-1¼-in. spaces between the boards. According to the size of the grains of sand, a sort of balance is more or less established between the heaps of sand on each side; but, contrary to what happens in the natural dune, the talus has its steeper slope on the side next the sea, while on the inland side the slope is much longer through part of the sand being driven, by the force of the wind, behind the paling, where it tails off gradually more or less according to the weight of the grains. When the palings are buried almost to their top, they are raised and the operation begins anew until the dune reaches the desired height, generally about 35 to 40 ft. above the high-tide level.

When raising the palings, the best form to give the dune is considered. The sandy deposits are examined, and the irregularity of the work performed by the wind is rectified by hurdles, brushwood, spikes, &c. When the desired outline has been obtained, the surface is fixed by planting tufts of the sea-marram, sea-matweed, or bent grass (*Psamma arenaria*, or also called *Calamagrostis arenacea*), a grass invaluable for this purpose, not only because it can be propagated both by slips and seed, but also on account of its throwing out long strands and forming new roots near the surface when the halms get buried in sand.

The outer dune being once formed and fixed, it only needs to be maintained properly. Constant inspection is required, and any damage done by squalls of wind or the impact of storm-waves must be repaired without delay. A special gang of labourers is always employed for this purpose, and the top of the dune is marked off with mile-posts to facilitate orders concerning work.

Of late years there has been a general tendency to make the side next the sea assume a longer slope by forming successive lines of fences made with pine-branches projecting about 2 ft. above the surface, at the foot of which the sand accumulates. These lines of hedges are in each case so arranged (and therein lies the art of the measure) as to result in the dune assuming the particular shape desired, and no time is lost in fixing with sea-marram all parts where this desired profile has been attained. But plants are afterwards pulled up or thinned here and there, to allow the wind to remove useless or inconvenient masses of sand.

The lines of fences parallel to the shore are often flanked with spurs running backwards at right angles, which are again sometimes spread out in spurs at their upper ends.

At points where rollers break without throwing up masses of sand, the violence of storms has to be checked by forming breakwaters of stone embedded in the sand and consolidated by growing Tamarisk, whose long flexible branches form a good protection. And at the same time efforts are made to form an artificial beach, with a slope of 5-6 per cent, to break the erosive force of the waves.

No definite contour or profile has yet been, and none is ever likely to be, found to suit the varying circumstances of all cases.

The fixation of the sand behind the outer dune takes place by sowing Maritime Pine seed and covering all the parts sown with brushwood to prevent the sand striking against and killing the seedlings. About 1000 bundles (4½-in. girth) of faggots (4¼ ft. long) are used per acre. Furze is preferable, then broom, then heather, fresh-water reeds, and Pine branches, but the latter have the drawback that fungous disease is often propagated from their leaves. Thorns, briars, brambles, and bracken give too little protection to be of much use.

Such covering of the sand takes place simultaneously with, or immediately after, the sowing of the seed, the brushwood being placed thick end outwards and the twigs of each overlapping the end of the previous row. This brushwood covering is kept down by a good shovelful of sand lifted from the parts not sown and laid along the twigs in lines about 2 ft. apart. Each labourer thus works backwards, following the sower, and at the end of each day's work the last row laid is firmly pegged down to prevent the wind lifting the brushwood during the night, which might spoil the whole thing.

The first sowings are made close to the littoral dune, and under its shelter. Thence they are year by year extended inland, each new breadth of sowing getting the benefit of the shelter given by the strips previously sown. Each newly sown part is also specially fenced with movable hurdles to protect it from drifting sand blown back by land-winds.

Thus a dead covering is first of all placed on the sandy soil, and replaced by a living protective mantle. In place of sowing Maritime Pine only, a mixture of about 26 lb. of Maritime Pine seed, and 2½ lb. to 3 lb. each of furze, broom, sea-marram or matweed, and also of other seeds to attract insectivorous birds, is sown per acre in the Coubre district; while in the Landes it has been found better to use 9 lb. Maritime Pine, 8 lb. of broom, and 3½ to 4 lb. of the marram seed per acre. All these germinate simultaneously; and the thicker the broom and grasses, the better the Pine grows. But the outer woods next the sea are usually rough and stunted for the first 200-300 yards in from the outer dune, and it is only to the lee of this broad protective fringe that the Pine can thrive properly.

Such operations are necessarily expensive, the average cost varying from £7 an acre at Coubre to £8 on the Landes. From Bayonne to Cape Grave the outer dune extends for 190 miles, and more than 150,000 acres of sandy waste have been fixed and planted.

In **Prussia**, as in **France**, the purchase and **planting of waste lands by the State** has been steadily carried on for more than the last twenty years. From 1883 onwards, when 34,500 acres of waste land were in hand, large tracts have been bought *en bloc*, and after the sale and exchange of parts suitable for agriculture or pasture, the plantable portions fit for forming large compact woodlands aggregate other 214,200 acres, of which 182,700 acres have now already been planted. The area annually taken in hand has varied from 5840 acres (1889) to 12,200 acres (1897), and has amounted to 9140 acres on the average, while the beating up of blanks extended altogether to 61,100 acres, or 3060 acres a-year on the average, and just over one-third of the area of one year's new planting. About 91,200 acres of "State acquired" waste land remain in hand still to be dealt with, and this represents nearly 1·43 per cent of the total woodland area of the Prussian State forests (6,498,300 acres).

The statistics from which I have taken the above details give no information about the planting; but the plantations, no doubt, consist mainly of Scots Pine or Spruce, according to the soil, like those also being made on a smaller scale by private associations, such as the Society for Moorland Cultivation in Schleswig-Holstein, which aims at the amelioration of the province by replanting waste lands and improving agriculture. It can merely work on a small scale, as its funds are only about £950 a-year (of which the State, the Province, and the Agricultural Chamber respectively contribute £275, £200, and £50); but it is very useful in providing the assistance of a head forester, in making advances for buying plants, and in giving prizes for successful plantings. Great difficulties have to be contended with. The soil is poor, and often impervious from moorpan, while climatic conditions are unfavourable. The Spruce seems specially suitable for planting, as, owing to the dampness of the air, it here grows fairly well even on poor sandy soil. Deep soil-preparation is necessary where there is moorpan, and beneficial where there is no pan; because, though it looks loose and porous, the sand is very fine-grained, and is all the better for being thoroughly broken up and aerated. Hence trenching in strips, with plough or spade, is preferable to pit-planting. Subsoil ploughing with a woodland plough and four horses costs from 20s. to 28s. an acre, while spade-work is dearer, and costs about ¼d. per running yard. Marshy spots have of course to be drained. Where the moorpan layer is not bad, the land can, with great advantage, be enriched with marl and artificial manure, and used first for rye, and buckwheat, and sheep-grazing before being planted. But where this cannot be done, then either the whole area must be steam-ploughed, or else trenches and mounds must be formed, the former costing about 32s. to 48s., and the latter 80s. to 120s. per acre. Protection against storms and blasting sea-winds is of the greatest importance. In exposed situations the Spruce plantations are mixed with Silver Fir, White and Menzies Spruce, and Pines. And as a protection against fire, the outer roadways are kept free of inflammable matter, the rides between compartments are ploughed and planted, wherever possible, with Oak, Birch, Alder, Silver and Grey Poplar, Mountain-Ash, and Larch. Plants and planting cost about 52s. an acre, and beating up blanks averages about 12s. an acre; but thus improved and stocked, the value of the woodland area is estimated at about £6 an acre. The price at which the waste land can be purchased in its unimproved condition is unfortunately not stated.

Similar work on a larger scale has been continuously undertaken by the Moorland Society of Denmark since its foundation in 1866, with the primary object of bringing the moors of Jutland into cultivation by drainage, planting, and road-making.

CHAPTER V.

THE TENDING OF WOODS AND PLANTATIONS.

WEEDING AND CLEANING, THINNING, PRUNING, AND PARTIAL CLEARANCE TO STIMULATE INCREMENT.

Protection of very young Crops.—Whether woodland crops be formed by natural regeneration or artificially by sowing or planting, all young woods and plantations usually require more or less of artificial protection against such dangers as frost, snow, wind, and drought, as well as weeds, insects, and fungous diseases, before they can establish themselves.

When woods are reproduced either naturally or by sowing under some of the mature trees, sufficient shelter can usually be given by leaving a certain number of trees per acre. Most of the trees grown for profit in Britain are hardy and of rapid growth at first, and soon outgrow danger from **frost** and **drought**. The light-demanding Larch, Pine, and Birch, as well as Oak, Ash, Elm, Maple, and Sycamore in a minor degree, are in these respects hardier than the shade-enduring Beech, Silver Fir, and Spruce. But when woods are sown or planted in the open, trees of rapid growth (Birch, Larch, Scots Pine) are often planted as "**nurses**" to protect the less hardy kinds, forming the bulk of the crop, from spring and autumn frosts. As nurses, Larch, Birch, and Pine have the advantages of being easy to transplant, rapid in starting to grow, and casting only a light shade on the other plants. In damp spots self-sown Willow, Aspen, and Alder can easily be utilised in the same way for protecting Oak or Ash. But all such "nurses" should be cut out as soon as they are no longer required.

Against **raw winds** protection may best be secured by making the annual falls of mature timber, or by planting young woods, in the direction directly opposite to the prevailing dangerous wind. This secures protection to the older woods against windfall, and at the same time gives the young new crops the benefit of shelter from the highwoods lying to windward.

Rank growth of **weeds**, whether soft grasses, bracken, and blackberries, or ligneous plants like furze, broom, heather, whortleberry, &c., or quick-growing softwoods like Birch, Aspen, and Willow, must be cleared away so far as they interfere with the young crop during the first year or two; and a careful lookout must be kept to prevent damage by rabbits, &c.

Such necessary weeding may perhaps only be confined to parts of the young woods and plantations; and in any case the amount of work thus involved varies so greatly with circumstances that it is impossible to say what it costs on the average. It may vary from 2s. 6d. or 5s. (one or two days of a man) upwards; but unless it is seen to in proper time, the young wood or plantation may be either badly damaged or ruined. Such charges for the first year or two should really be included in reckoning the original cost of the young crop.

Young seedling growth in natural regenerations and sowings is sometimes so crowded that many of the plants become half choked and so drawn up in their struggle for light and air as hardly to be able to bear their own weight. In shade-enduring kinds this struggle is continued longest, while with the light-demanding kinds the natural process of selection is more rapidly effected. Yet in both cases artificial aid, promptly given, benefits the young crop. If many of the young plants cannot be lifted for transplanting, the best and cheapest way is to cut off weaklings close to the ground with shears. If delayed too long, the excessive number of plants must be cautiously reduced, else the saplings left are unable to support themselves and easily get bent down by snow. Where such danger exists, it is best to cut narrow lines through the thicket to allow the plants at the edge to grow more rapidly than those between the lines. In plantations, of course, there is seldom any danger of this sort; and most young crops, whether natural or artificial, are more likely to be too thin than too crowded for the first five or ten years. Where blanks occur, they should be at once filled by planting whatever kind of tree is best suited for the soil and situation.

If the general growth of the young crops is backward, they may be improved by planting a few Scots Pine, Larch, Douglas Fir, or Birch on dry or fresh soil, or Aspen, Willow, and Alder on moist land. Single rows of such trees planted far apart have a stimulating effect on backward crops of Oak, Beech, Spruce, and Silver Fir. But here again, such rows of nurses should be gradually removed whenever the object in view has been attained.

Tending of Crops when once established.—When once the young woods and plantations can be considered to have established themselves, different operations of tending are still necessary through all the other remaining stages of growth as thickets of saplings, young pole-woods, or fully developed highwoods. The way in which woods and plantations are tended affects the whole of their subsequent development. The quantity, the quality, and the market value of the future mature timber crop are all more or less dependent on the way it has been tended by cultural operations, all very much of the character of thinning. These measures include:—

1. **Weeding and cleaning**, so long as the value of what is cut out fails to cover the cost of the operation,—so that it therefore forms a charge against the young crop.
2. **Thinning**, when the cost of cutting out poles, &c., is covered, or more than covered, by the value of the produce removed.
3. **Partial clearance** of poles or trees after the main growth in height has taken place, made to stimulate increment in girth, or to prepare for seed-production and natural regeneration.

1. **Weeding and Cleaning** are practically identical with thinning, the only difference being that they are cultural charges just as properly debitable to the original cost of forming the woods as are soil-preparation, sowing, planting, filling of blanks, &c. The cost of weeding and cleaning is generally greater in natural thickets or thick sowings than in plantations. Sporadic growth of hardwoods and softwoods has often to be cleared away, so that young crops, raised either naturally or artificially from seed, are generally more or less interfered with by coppice-shoots or invaded by self-sown Birch, Aspen, or Willow. These are often useful in helping to fill up the crop; but if (or when) not required, they are difficult to get rid of, as they throw up numerous stool-shoots and suckers when cut back. Having small, light, winged seeds, these softwoods spread far; and as their foliage produces the intermediate forms of fungous leaf-diseases on Larch, Spruce, and Pine, it is well to reduce their number in Conifer woods.

Weeding consists in the removal of all such trees, except to any extent desired for filling blanks, together with the cutting back of rank grasses, and other herbaceous and ligneous growth; while **cleaning** is the removal of all such weaklings forming part of the original crop as may, if left longer, compete with the better part for light and air,—such as the cutting out of "nurses" when no longer needed.

Here the object is not to remove as much as one safely can, but to confine the operation merely to what is best for the growth of the future crop. Weeding and cleaning may have to be repeated more than once; but where small poles are saleable as pea-sticks, hop-poles, &c., early **thinnings** should soon be profitable.

Careful **weeding** and **cleaning** are the best means of obviating damage by snow-break, insects, and fungous diseases. Neglect of early tending soon dissipates the vital energy of the crop, and causes this to consist of an unnecessary number of small stems of little value, while the more valuable trees are crowded out and suppressed by kinds of less value; and ultimately the crop may have to be prematurely cleared at a loss, instead of a profit.

As in weedings in very young crops, the cost of further weedings and cleanings also varies greatly according to local conditions in each case. No average cost can be safely estimated.

Weeding of Coppice is to be recommended, wherever necessary, because the softwoods and less valuable kinds of trees usually throw out stronger shoots than the more valuable, whose cultivation is the main object. A little outlay in this way during the second year, and repeated a year or two later if necessary, is much more profitable than allowing the whole crop to grow up unrestrictedly. Osier-holts, Oak-bark hags, and Ash-groves should be kept pure and free from any unintentional mixture of other kinds of trees; and even in ordinary copse underwoods, the patches of Hazel, Ash, Chestnut, &c., should be kept free of spreading softwoods like Birch, Lime, and Sallow, except when these are needed to fill blanks where one has not been able to flush shoots of a more profitable kind. And at the same time it may be desirable to clean (thin) the young crop by removing weakling shoots where the stools have sent out a numerous flush, as the four to six good rods left standing grow into more money than eight or nine weaker shoots. Unless such a cultural measure be taken in hand within the first two or three years after each fall of the coppice, it is then too late to do the work properly. The thicket becomes too dense to have a proper view of the stools, and to bring out the young shoots if they should be worth bringing out.

Osier-holts should be weeded and cleaned by frequent holing and forking between the lines in spring and early summer, otherwise only a light crop of rods will be harvested. Cleaning should be completed by the end of June. For the first two years it costs £1 to £2 an acre, but after that it is much less, because the Osiers, if kept clean in spring, often grow 18 inches in a week, and then soon suppress weeds.

Cleaning of Continental Coppices—These differ considerably, in their composition, from English coppices. In place of only Ash, Hazel, Chestnut, &c., being saleable, mostly for specific purposes and of certain sizes, there is a constant demand for all sorts of small wood, including Beech, Hornbeam, &c., almost unsaleable in Britain. A fair idea of the German treatment of tending coppice may, however, easily be conveyed.

With the low rotation usual in coppice-woods the soil is laid bare frequently, and it is therefore necessary to safeguard its productivity. This is all the more requisite, the less fertile and fresh the soil may be. The only cheap and effective way of doing this is to mix shade-enduring and soil-improving species with light-demanding kinds. For light or limy soil the Beech is to be recommended, while on moister land the Hornbeam yields better results. Within a matrix of one or other of these two species, the light-demanding kinds may best be grown in small patches. On loamy or limy soil Maple, Sycamore, Elm, Lime, Oak, and Hornbeam often naturally appear along with the Beech, and by cleaning the young crop a good deal can be done, even without much sowing or planting, to obtain a favourable mixture; while on fresh sandy or mild loamy land softwoods usually grow spontaneously to such an extent as to necessitate their partial removal by weeding and cleaning.

In coppices Beech is at a disadvantage with most other species, because its general reproductive capacity is naturally less vigorous, and its shoots are of less rapid growth than those of most other trees. It yields its best returns when growing with Ash, Hornbeam, and Birch on good fresh land.

Among the other species grown along with Beech in mixed coppices, there is, of course, also an individual struggle for growing-space; but when the soil is good the stools are not too crowded, and the softwoods apt to spread horizontally only occur in very subordinate number, so that Ash, Maple, Sycamore, and Hornbeam or Elm on deep land, and Oak on warm exposures, can maintain themselves well, more especially when some little assistance is given in the way of cleaning. The Ash generally holds out well in coppice-hags on suitable soil, even when its shoots are somewhat hemmed in laterally. But where there is much Birch, Lime, and Hazel, which all three tend to spread, these soon interfere with the hardwoods; and if suckers of Aspen, Alder, Hawthorn and other shrubs, of rapid growth at first but soon falling off, also make their appearance, then the hardwoods run the danger of being outgrown and finally suppressed. And this danger is all the greater, the less the soil and situation may be suited for the particular requirements of the hardwoods (Gayer, *Waldbau*, p. 264).

Filling of blanks is also a necessary measure of tending usually required for the first two years in all young plantations. The number of plants which, from one cause or another, fail to establish themselves, may of course vary greatly, but it is generally wise to retain close at hand in a temporary nursery or a corner of some compartment a reserve of about 10 per cent of the number planted out. Thus for planting at 4×4 ft. (2722 per acre) it is well to pro-provide 3000 per acre, keeping the balance as a stand-by for beating up blanks. The replacement of dead plants can usually be most conveniently taken in hand in autumn, and any plants then left can always be utilised elsewhere in the following spring.

Backward plantations of hardwoods can often be improved about two or three years after planting, by cutting back close to the roots any stems that are still wilting. This gives them a better chance of coming away more freely.

2. **Thinning in Pole-woods and young Highwoods.**—In Forestry the term "thinning" is only applied properly to the cutting of diseased, suppressed, or badly-grown stems whose removal will be of benefit to the rest of the crop, consisting of all the more energetic and the healthier individual trees; and these latter are left in the largest possible number to which they can find the proper physiological conditions for healthy growth and development, and for the production of the greatest amount of timber under the given local circumstances as to soil, elevation, aspect, &c. The practice of so-called "thinning" which obtains throughout most parts of the United Kingdom is to cut out prematurely many of the dominant poles and trees, thus giving the weaklings "a chance of coming up," as the saying goes, and overlooking the fact that by removing many of the largest and best poles the vitality, the productivity, and the ultimate value of the final crop are distinctly and absolutely irreparably prejudiced. Mistakes of this sort, once made, can never be rectified. It is just like taking the cream off milk, or the raisins out of a plum-pudding or a cake, and expecting what is left to be still as rich as it was before,—which is absurd. And again, any such unnecessary degree of thinning, by inducing a considerable increase in foliage, increases the leverage obtained by the wind during storms, and greatly diminishes the mechanical support which the crowns of trees afford each other during violent gales.

The **principle of thinning** is nothing more than the *conservation of physiological energy*, and the best utilisation of this with the specific object of growing the largest quantity of marketable timber per acre, of the best quality and the highest market value for the whole crop that can be produced on the given soil and situation. If one plants at 4×4 ft., the 2722 plants per acre cannot all grow up to maturity. As the young trees grow upwards and expand sidewards, an *individual struggle for existence* sets in, and the quicker-growing kinds or individuals outgrow and suppress slower-growing genera or less vigorous plants. If left to nature this struggle for existence is slower on poor than on rich soil, and slower on unfavourable than on favourable situations; but it always dissipates the vital energy of the crop. This can only be conserved and utilised for timber-growing by means of thinning. **Thinning** therefore includes all operations for removing unnecessary species or individuals in pole-woods and young highwoods until **partial clearances** can be made, after the chief growth in height has been completed, for increasing the growth in girth or for reproducing or regenerating and harvesting the mature timber-crop.

The ultimate yield in timber depends greatly on the way thinnings have been made. The crops which stand most in need of being thinned, and of frequent thinning, are those in which the stems are all of about the same age and rate of growth, because the individual struggle for existence is then more prolonged than where some plants have an advantage to begin with.

When plantations have been formed at about 4×4 ft. there should usually be little or no thinning required till about fifteen years of age for light-demanding trees (Oak, Ash, Larch, Pine, &c.), or till about twenty years of age for shade-enduring trees (Beech, Douglas Fir, Spruce, Silver Fir), though of course this will vary by two or three years on either side according to soil, situation, and the local opportunity there exists for selling small poles profitably.

Exceptional circumstances may make even much earlier thinnings profitable. For example, 5 acres of Larch recently planted in Hants at 2½ ft. apart for small hop-poles, at seven years old gave 10,000 marketable poles; but the result of such close planting of pure Larch was that many of the poles left were badly cankered, as the district was infested with the fungus.

After the struggle for existence has commenced in earnest in young and middle-aged woods, poles or young trees may be roughly classified as belonging to one or other of three classes—(1) **dominant**, (2) **dominated**, and (3) **suppressed**. Suppressed stems that are dead or dying should always be thinned out as soon as convenient, and the thinning must go further than this to be of any use in increasing the ultimate mature yield of the crop.

As, during the gradual process of death and decay that takes place when suppressed stems become moribund, certain physiological conditions obtain which are extremely favourable to the breeding of insect enemies and the propagation of fungous diseases, this last class of stem should invariably be removed during thinnings. By this means a freer circulation of air and a better utilisation of the soil-nutrients are also at the same time effected.

To what extent a simultaneous removal of the suppressed and the dominated classes should proceed, depends in each case on soil, situation, kind of tree, age of crop, mode of treatment, &c. If the struggle were left to nature unassisted, it would be carried out most rapidly on fertile soil; but, on soil of merely average or inferior quality, it would be so much prolonged in the case of shade-enduring trees as to result in overcrowding throughout the pole-wood and the young high-timber stages of growth.

From the sylvicultural point of view, however, the main objects of care are the timber-trees which it is desired to utilise on their attaining maturity; and any measure that will aid in stimulating their rate of growth is desirable. Year by year the number of stems diminishes from which the future mature crop must be formed, and the removal of all unnecessary stems not only improves the growth of the dominant portion of the crop, but also becomes a source of revenue, to be realised as soon as convenient, so as to reduce the amount of capital invested in the crop. And these intermediate returns from thinnings are often considerable, where any fairly good market exists for poles and pit-props. (*Studies in Forestry*, chap. ix.)

The preliminary or **intermediate yield from thinnings** under the German system of growing timber in close canopy has been found to be as follows :[1]—

Granted that thinnings begin at the proper time—in the case of Scots Pine about the fifteenth to twenty-fifth year, Spruce about the twentieth to thirtieth year, and Beech about the twenty-fifth to thirty-fifth year,—that they are regularly conducted, and that the yield is not reduced by any local circumstance (right of collecting windfalls, snow-breakages, &c.), the average proportion which the intermediate yield from thinnings may be expected to bear to the final mature yield will be (Grebe, *Die Betriebs- und Ertrags-regelung der Forste*, 1879, p. 300):—

(1) In *Scots Pine woods*, with a rotation of—

60 years, from	18-24 per cent.	The higher percentage is obtainable from inferior soil.
80 " "	22-28 "	
100 " "	about 25 "	

(2) In *Spruce woods*, with a rotation of—

60 years, from	15-17 per cent.	The higher percentage is obtainable from inferior soil.
80 " "	20-22 "	
100 " "	23-26 "	

(3) In *Beech woods*, with a rotation of—

80 years, from	12-20 per cent.	The lower percentage is obtainable from poor soil, the higher from better soil and situation.
100 " "	14-25 "	
120 " "	16-30 "	

The *first thinnings* at fifteen to twenty years of age (according to demand for light) will usually remove one-quarter to one-half of the original crop (2722 at 4 × 4 ft.) A *second thinning* will usually be necessary about five years later, and a *third thinning* about other five years later, when there will probably be at twenty-five to thirty-five years of age (for light-demanding and shade-enduring crops respectively), only from 700-900 and 1000-1200 stems per acre on the average in Britain, although the stock might usually be quite well maintained at 800-1000 and 1200-1500 per acre respectively.[2] After that, the later thinnings may have to be repeated at intervals of five to ten years, according to circumstances. The work should be done methodically, a regular *Plan of Weedings and Thinnings* being forecast by the forester and worked up to year by year, so as to go over, say, one-tenth of the middle-aged and older woods each year, and one-fifth of the pole-woods and young tree-crops. After about 40-50 years of age little or no thinning is required in conifer crops, except merely to remove moribund and sickly stems.

The thinning of mixed woods must be conducted on a different principle from the thinning of pure woods. To save Oak, Ash, or Larch, it may often be necessary to fell more vigorous poles of other but less valuable kinds, which are interfering with or threaten to dominate those.

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[1] Fuller details will be found in the Average Yield Tables in vol. ii., Part V., *Management of Woodlands.*

[2] Hüffel gives the following mean figures for Scots Pine in North Germany :—

Age of crop.	Number of trees per acre, soil and situation being—		
Years.	Good.	Average.	Poor.
40	700	1220	2280
50	460	820	1600
60	320	600	1120
70	260	440	800
100	170	250	430

In Germany the average number of stems per acre in pure woods grown in close canopy is (but see also vol. ii., Part V., Appendix III.):—

Age of crop.	Scots Pine (after Weise).		Spruce (after Lorey).		Silver Fir (after Schuberg).		Beech (after Baur).	
	Soil quality.		Soil quality.		Soil quality.		Soil quality.	
Years.	I. (Very good.)	V. (Very poor.)	I. (Very good.)	IV. (Very poor.)	I. (Very good.)	V. (Very poor.)	I. (Very good.)	V. (Very poor.)
20	1420	...	2560	Data not available.	2980	...	...	...
40	720	1810	1050		1370	4470	1360	...
60	370	1040	500		530	1780	500	1480
80	240	730	310		310	890	320	730
100	170	...	240		220	560	250	450
120	140	...	220		170	400	190	350

While the average cubic contents (true measurement) of the entire stem have been found to be:—

Age of crop.	Scots Pine.		Spruce.		Silver Fir.		Beech.	
	Soil quality.		Soil quality.		Soil quality.		Soil quality.	
Years.	I.	V.	I.	IV.	I.	V.	I.	V.
	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
40	6·4	1·0	6·1	Data not available.	4·6	0·3	2·5	...
60	18·0	2·5	18·3		19·4	2·1	11·8	1·0
80	33·4	4·3	42·1		41·0	5·7	25·2	3·6
100	54·0	...	61·9		64·4	11·8	40·6	7·5
120	70·2	...	70·5		87·4	18·7	63·0	12·2

And the total average production per acre (exclusive of thinnings, but including lop and top below 2·8 inches in diameter as well as timber) is approximately:—

Age of crop.	Scots Pine.		Spruce.		Silver Fir.		Beech.	
	Soil quality.		Soil quality.		Soil quality.		Soil quality.	
Years.	I.	V.	I.	IV.	I.	V.	I.	V.
	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
20	2,340	820	2,200	500	1,010	170	1,160	240
40	4,870	1,920	6,460	1,850	6,740	1,500	3,590	920
60	6,840	2,710	10,770	3,810	10,490	3,550	6,120	1,620
80	8,250	3,230	13,390	5,320	12,930	5,360	8,410	2,620
100	9,230	...	14,920	6,330	14,440	6,720	10,450	3,490
120	9,910	...	15,950	7,250	15,370	7,650	12,190	4,300

Although on poor soil there are frequently more than twice as many stems per acre as on good soil, yet the growth in height and in girth are often less than half of that on more favourable localities, while the total production of wood at no time amounts on inferior soil to half of that attained on soil of the best quality (*British Forest Trees*, p. 43).

Owing to the prolongation of the struggle for existence on poor soil, the average growing-space per stem is often much less than on better soil, although in Scots Pine this difference is less marked than in any other tree. This practically means that on soil of about average quality, the golden rule of tending woodlands is to **thin early and moderately,** and to repeat the operation whenever necessary. This is far better than making drastic thinnings at long intervals.

One of the peculiarities of British Forestry has always been, and still is, unnecessarily severe thinning, based on the national system of growing Oak for the navy in former times (see *Introduction*, p. 28). Thus Brown (*The Forester*) recommended that for ornamental plantations and park or lawn trees a distance from stem to stem about equal to the height of the trees should be maintained at all stages of growth, while—

If it is intended to rear up a plantation of Firs or Pines for the sake of shelter and timber, the distance between each tree may be about one-third of the height, which is the distance found most favourable to the useful development of the Fir and Pine tribes as timber-trees.

Again, Campbell Walker (*Report on English and Scotch Forests*, 1872), in speaking of the Scone woods, says:—

Mr M'Corquodale (head-forester to the Earl of Mansfield) lays it down as a rule that the average distance between trees in a plantation should be one-third their height. Thus, if trees average 30 ft. high, they should stand 10 ft. apart, and so on.

Twenty to thirty years ago most British foresters acted, and many still act, on this misguiding principle, according to which a shade-enduring Douglas Fir, Spruce, or Silver Fir would require a growing-space as large as, and often larger than, a light-demanding Larch or Pine—which is absurd. It may be a good enough rule-of-thumb for Arboriculture, where ornamental effect and not profit is the main object; but it is impossible for timber crops thus treated to yield any but rough knotty wood of far less market value than the long, smooth, clean timber grown in close cover on the Continent. It is this severe thinning, and not either the soil or the climate of Britain, which makes British Conifer timber smaller and less valuable than the Larch, Fir, and Pine grown in other countries. The bad results of such treatment may be judged of from Figs. 62 and 63, which have been reproduced from recent photographs.

When trees are allowed a large growing-space they produce more wood per stem than those that are confined within narrow limits, because they can draw more food from the soil and have more sunlight for assimilation. If the growing-space is too confined, the crop becomes crowded, and the poles are drawn up rapidly without attaining the due proportion between the height and girth necessary for stability. The future value of the crop depends greatly upon the trees being allowed sufficient growing-space during all the various stages of their growth. But even the growth in height may be checked if young woods are overcrowded.

Although isolated trees do not grow so high as those that are drawn up in close canopy, yet when a young pole has not the necessary growing-space for the proper expansion of its crown, its physiological requirements cannot be properly supplied: neither its roots nor its foliage can obtain the full amount of food and bright sunlight necessary for really vigorous nutrition, and the consequence is that its whole energy of growth (including growth in height as one expression of this) becomes checked. The long struggle between individuals in crowded woods therefore affects growth in height, growth in girth, and growth in total cubic contents.

Fig. 62.

Mixed Wood of Larch and Spruce, with some Scots Pine, mature and about to be felled (*Taymount, Perthshire*, 1900).

The bad effects of heavy thinning in the past are here noticeable.

Fig. 63.

Scots Pine Plantation at 28 years of age (*Beaufort, Inverness-shire*, 1899).

Showing excessive branch-formation, due to unnecessarily heavy thinning.

The only sound rule that can be given is to allow each pole or tree merely sufficient space for the healthy action of a moderate size of crown, but not to give so large a growing-space as may encourage the spread of the branches at the expense of the stem, or may prolong the life of the lower branches so much as to affect its technical and market value. Between these two extremes of overcrowding and far too large an average growing-space there must be for every kind of crop, and on every soil and situation, a happy mean,—and this is called the **normal density of canopy**. This of course varies with the relative demand for light made by the different kinds of trees, and with the fertility of the soil.[1]

The older the crop, the more light-demanding the kind of tree, the better the soil, and the more favourable and sheltered the situation, the greater will be the mean average growing-space required per stem.

In explaining the **theory and practice of thinning**, Gayer (*op. cit.*, pp. 550-558) points out that the necessity for thinning depends on the following factors :—

1. **Age of Crop.**—During the first third of its life-period, the natural process of eliminating superfluous stems is relatively much greater than during the later stages of growth.
2. **Kind of Tree.**—In comparison with **light-demanding trees** (Scots Pine, Larch, Oak, Birch, &c.), the **shade-enduring** trees only require about one-half to two-thirds of the average growing-space needed by the former.
3. **Soil.**—Until about sixty to eighty years of age, the average growing-space on poor soil is often much less than on good land ; and such difference in number is all the more marked the less light-demanding the tree forming the crop may be.
4. **Elevation.**—The higher the locality, the greater the number of stems per acre, but the smaller the trees are in height, girth, and cubic contents.
5. **Aspect.**—Hot S. and W. exposures carry a larger number of stems than N. and E. aspects.
6. **Slope.**—On hillsides there are more stems than on level land, as more light is available ; but this is practically balanced by land on the plain being generally deeper and better than that on hillsides.

All these factors necessarily affect thinning operations. Young woods raised by natural regeneration or by sowing are usually at first much denser than plantations ; and in both the need of thinning is greatest during the pole-stage of growth, when assistance given in the struggle for supremacy tends to conserve the energy of the favoured individuals and to increase their production of wood. Again, light-demanding kinds naturally require more growing-space than shade-enduring trees. And finally, wherever, owing to poor soil, high elevation, or exposure, the struggle for supremacy is long-continued, matters have to be assisted

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[1] The struggle for existence on crowded areas extends to (Ramann, *Forstliche Bodenkunde und Standortslehre*, 1893, p. 459)—

1. Imbibition of soil-moisture and absorption of soluble nutrient salts from the soil by the root-system.
2. The crowns interfere with each other's supplies of light and air, while the root-systems become abnormally developed in trying to get sufficient supplies of moisture and food.
3. The physical condition and properties of the soil deteriorate.
4. The normal process of humification of dead foliage and fallen twigs is interfered with.

These factors are always more or less concurrent in the struggle which takes place in crowded woods, and it is often difficult to say, in any given case, which is the main cause interfering with the growth of the crop.

by a somewhat heavier thinning than on good soil and a favourable situation. And this is specially the case where there is danger from wind, snow, and ice. On inferior land the thinnings should (in order that the soil may not deteriorate) be slighter, but more frequently repeated, than on good soil.

How often thinning should be repeated depends mainly on the age and the growth of the crop, and on the kind of tree. It has to be done oftenest in pole-woods of light-demanding trees, such as Oak, Ash, Larch, Scots Pine, and should, if possible, be repeated every five years; while in pole-woods of the shade-enduring Douglas Fir, Spruce, Silver Fir, and Beech, once every eight or ten years during the pole-stage of growth is usually quite sufficient.

A thinning is said to be **slight** when only dead or dying poles are removed, **moderate** when all suppressed poles and also part of the dominated class are cut out, and **heavy** when all the suppressed and dominated poles are at the same time eliminated. So long as it is not so heavy as to affect the growth in height of young crops, a free thinning hastens on the maturity of the crop, and is therefore a profitable operation.

In middle-aged timber crops *a slight thinning* removes about 5 per cent of the basal area of the stems at breast-height in crops of normal density, *a moderate thinning* about 10 per cent, and *a heavy thinning* up to about 15 per cent. Where it goes beyond this last degree, it in reality becomes a partial clearance.

In France, and now also in Germany to a certain extent, badly-grown *dominant* trees are thinned out, while suppressed (though otherwise healthy) stems are left, because they do not interfere with the growth of the former, but protect the soil against deterioration. This refers, however, mainly to middle-aged woods (and to Oak in particular); and a particular term is used for this kind of thinning among dominant stems (*Hochdurchforstung; Éclaircie par le haut*, or *éclaircie sur l'étage dominant*). It reduces a highwood to something like the condition of standards over coppice, and has special reference to the growing of Oak in mixed woods.

This method of thinning, entirely French in origin, and introduced in the reign of Charles IX. (1560-1574), is thus described by Boppe et Jolyet (*Les Forêts*, pp. 170 and 172):—

Thinning in the dominant class removes poles or trees whose foliage extends on much the same level as that of the other trees whose position it is desired to improve. The fundamental principle is here to maintain intact the completely dominated trees. All the stems which have entirely given up the struggle for light, all those which are now compelled to vegetate at a lower level than their more vigorous competitors, all the intermediate stages, and all the more or less shrub-like underwood, are left intact. Their removal is unnecessary, because their crowns of foliage no longer compete with those of the trees that will form the future mature crop. It would be a mistake for three reasons: (1) by leaving them intact one can thin all the more freely among the dominant trees without fear of laying bare the soil; (2) the dominated stems can often recover sufficient vigour to replace some good tree destroyed by accident; and (3) this intermediate vegetation forms a screen which protects the boles against direct sunlight, kills off the lower branches, and naturally assists in cleaning the stem. Thanks to them, one can give the trees forming the mature crop of the future the best conditions for producing good timber—a free crown, a well-shaded bole, and the soil kept cool and moist around their roots. . . . This method of thinning suits, better than any other, our national aim of growing fine trees in place of crops often of monotonous uniformity.

The same idea has long obtained in Germany, where it was found that thinning requires to be heavier in Oakwoods than in any other kind of crop.

One may hold only to *moderate* thinning in general; but so far as the Oak is concerned, something more than that is necessary. Without interrupting the leaf-canopy to any injurious extent, the thinning of crops or patches of Oak must be begun *early*, and be repeated frequently till the age of tree-forest, unless the second portion of the life-period is to be passed over underwood formed after a partial clearance extending beyond the limits of a mere thinning. Crowding of the individual trees, indefiniteness with regard to the predominating class of stems, and a long struggle for supremacy, are even less desirable in Oak-woods than in other crops; hence the thinning must be of a *somewhat anticipatory nature*, and must include all stems that are not necessary for the maintenance of the leaf-canopy. In the older woods, even the formation of small blanks, caused here and there by the removal of trees, need not be avoided; for they soon close up again. In *early and oft-repeated thinning* lies the best tending of the Oak; and for the maintenance of a good leaf-canopy, the *frequent* removal of individual trees of backward growth is often the most prudent measure. When the axe has been early and often made use of in Oak-woods, good intermediate returns are not only obtained from the timber and the bark, but at the same time the most favourable conditions are secured for the growth of the trees forming the main crop, while the best development of stem and crown is also attained. (Burckhardt, *Säen und Pflanzen*, p. 9.)

This system, which arose in France from the predominance of Oak in copses and highwoods, and refers chiefly to broad-leaved woods, has some resemblance to the customary British way of thinning heavily among the dominant poles and young trees in Conifer plantations, when a good many fine poles are cut out "to let the others come up." But there is this great difference, that whereas the heavy thinning among dominant poles in Britain is done mainly to get early income from the plantations, and intentionally discounts part of its value when mature, on the Continent the object is to make the ultimate mature crop as large and valuable as possible (see remarks and tables in *Introduction*, pp. 51-55). Unless Scots Pine woods and plantations are cleared of suppressed stems, the dead and moribund poles or trees soon become attacked by insects and fungi, and such treatment as above would there be extremely rash.

The Gurteen-le-Poer method of treating mixed crops of Larch, Scots Pine, and Spruce (Larch predominating), which has already been incidentally mentioned in the *Introduction* (p. 97), essentially belongs to the system of practical clearance to stimulate increment. It is the usual way of treating mixed Conifer plantations in S.E. Ireland, but is perhaps practised with more of systematic regularity on the Gurteen-le-Poer estate in Co. Waterford (Count de la Poer) than elsewhere. It is based on the fact that the only way of disposing of the timber is as pit-wood for England and Wales. The plantations are made at 4×4 ft., and are thinned for the first time at about fifteen years of age, when rubbish is cleared away and the dominant class of stems is "thinned" to the extent of about 580 poles, giving about 20 tons weight of timber (pit-wood down to 3 in. top-diameter). About five years later a second "thinning" is made, removing about 500 poles or 25 tons weight. A third "thinning" about twenty-seven years of age removes about other 380 poles or 20 tons weight, a fourth at thirty years removes about 360 poles or 30 tons, and the remainder of the crop is cleared at about thirty-five years of age, giving about 240 poles or 20 tons weight. Thus the 2722 plants per acre furnish about 2060 (or 76 per cent) marketable poles, weighing about 115 tons of pit-wood (or 18 to the ton). The land is then cleared and replanted.

This method being solely for growing pit-wood, the main object is to get as many of the originally planted 2722 per acre as possible up to the required size. Whether by planting at $4\frac{1}{2} \times 4\frac{1}{2}$ ft. *all* the 2150 poles per acre might then be made marketable as pit-wood is an open question.

Continental experience has shown that the height of timber crops, besides being practically proportional to the suitability of the soil for the given kind of tree, is, in all homogeneous crops growing under similar conditions, as a rule proportional to their basal area until their chief growth in height is completed. But when the conditions of growth vary (as must be the case when, *cæteris paribus*, certain woods are only *slightly* thinned, and others *moderately*, or perhaps even *heavily*), then the natural proportion between height and girth becomes more or less interfered with. The closer the leaf-canopy, the more the form of the bole approximates to the cylindrical; and the larger the growing-space, the greater is the tendency to a conical form of bole and lateral expansion of crown and branches. Experiments carried out in Beech and Scots Pine woods by the Forest Branch of Munich University went to prove that, "when thinnings were carried out freely, the development in height was relatively much greater than the diametral increment; and that at any rate during a certain period in the growth of crops, the heaviest degree of thinning produced the loftiest and the cleanest boles."

Of course, the correctness of this statement, or of any other dictum with regard to most of the operations of practical sylviculture, depends in each case on the nature and condition of the crop as to kind of tree, age and mode of formation of crop, condition previous to and at time of thinning, nature of soil and situation, &c. But Weise (*Chronik*, 1881, p. 25) seems perfectly correct in making the broad generalisation that, "when a crop is too thick, increment in height and in girth both suffer to an extent not compensated by the out-turn yielded from the greater number of stems; when it is too thin, however, the crop remains backward in growth in height."

Experiments made to try and discover a natural law regarding the different effects of slight, moderate, and heavy thinnings on growth in height, girth, form of stem, and total yield of timber per acre, have failed to give any practical result. On the whole, they simply confirm the wisdom and practical value of the rule, founded on experience, that "*thinnings should be begun early, carried out moderately, and repeated as often as necessary*." This does not in any way affect the correctness of the theory and the practice of partial clearance, after once the chief growth in height is completed, for stimulating rapid increment in girth and improving the shape of the bole. (*Studies in Forestry*, p. 194.)

The Value of Thinnings cannot possibly be averaged, because this entirely depends on the local demand for small poles, &c. (see *Introduction*, p. 97). Up to about the twentieth year for light-demanding trees, and to about the thirtieth for shade-endurers, the income from this source must necessarily be mainly dependent on the ability to dispose of pea- and bean-sticks, poles for ornamental fencing, hop-poles, and small-sized pit-wood; and whether or not one may get either 1d., 2d., 3d., or 4d. a-pole for small material, depends entirely on demand and supply. In most parts of Great Britain and Ireland, where large plantations might possibly be made on poor land, the demand for wood of less than pit-prop size (down to 2½ in. top-diameter) is now very small; and such material will not stand heavy expense in long transport by road or rail.

Two very obvious deductions that may be drawn from the data given on pp. 51-55 of the *Introduction* are, first of all, that we have no reliable British statistics enabling us to strike any rational average as to what number of trees or quantity of timber our woods and plantations ought to contain at twenty, thirty, forty, or fifty years of age on woodland soil classifiable as *good*, *fair*, *average*, *inferior*, or *poor*; and secondly, that even if such reliable data were available to a satisfactory extent, yet the results they might give would certainly not represent the true productivity of the soil *if the woodlands were throughout their whole life-period treated on purely business*

Fig. 64.

Old Scots Pine-wood, with natural undergrowth of Birch here and there (Muirward, Scone, Perthshire, 1900).

principles.[1] Each of the plantations to which the Irish statistics quoted refer, would have had a larger and more valuable crop of timber if it had not been subjected to very heavy thinning.

This hereditary tendency to heavy thinning is partly the outcome of the old national system of growing Oak for shipbuilding, and is partly intended to promote ornamental effect and provide better cover for game. But its direct results are, as shown in Figs. 62 and 64, illustrative of a mature Scots Pine wood, (1) to decrease the total quantity of timber per acre at from thirty to fifty years of age; (2) to cause the poles and trees to be rougher and more knotty and branching (and consequently of less value) than if grown in close canopy; and (3) to render the woods much more liable to damage during heavy gales, such as occur at least once every ten years or so on the average. Another disadvantage, as far as the production of large timber is concerned, is (4) that excessively heavy thinning leads to the crop becoming mature, then over-mature and needing clearance, at a much earlier date than would otherwise be necessary. When they stand more or less completely isolated, the stems thicken in girth near the base, at the expense of length and cleanness of stem; and the result is that the culminating point as to rate of growth per stem, and per acre as a crop, is reached and passed earlier than would be the case under more conservative treatment for the production of the largest and most profitable crop of timber that can be grown on the given soil and situation. This more purely national-economic point of view is not one which any private landowner can be expected to accept as a matter of course. The few landowners who are still able and willing to invest money in plantations are in every way justified in adopting whatever treatment they like with their own property; and it is very easy to understand their desire to have the young woods thinned heavily as soon as the poles become marketable, because this brings back some return for the investment made, and usually makes the woods better fitted for game preservation, while it undoubtedly renders them objects of greater natural beauty than are the dense, bare pole-woods worked on purely business principles. Thus it usually happens that whenever stout poles or posts are wanted, either for estate work or by a purchaser, the forester goes into the woods, and in a haphazard sort of way cuts out whatever number is required, or is wanted by a buyer,—and the poles or posts taken are usually selected from the dominant class. Now, this is not really a *thinning* at all; it is a *partial clearance* or premature utilisation of the more energetic stems, which should be left growing to form the ultimate crop of timber for harvesting when mature.

[1] German statistics both for intermediate and final yield will be found in vol. ii., Part V., *Management of Woodlands*, but they can give no assistance whatever in estimating the money value of thinnings from young woodland crops in Britain. In Hanover it was found (Burckhardt's *Hülfstafeln für Forsttaxatoren*, 1861) that one might reckon as obtainable from thinnings *an annual average in cubic feet per acre* as under :—

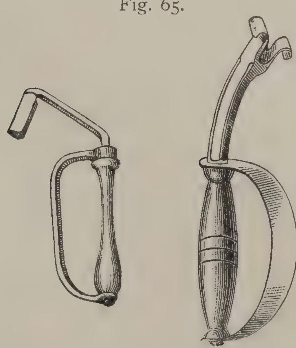
Crop.	Age.	Quality of soil and situation.			The maximum is obtainable at age of
		Good.	Average.	Inferior.	
	Years.	cub. ft.	cub. ft.	cub. ft.	Years.
Oak	20 to 100	37-45	30-37	22-30	...
Beech	30 to 90	24-30	15-20	8-10	40 to 50
Scots Pine . . .	20 to 60	30-40	24-36	15-27	20 to 30
Scots Pine (if not thinned till 25 to 30 years of age)	30 to 60	30-36	24-30	13-18	...
Spruce	30 to 80	36-48	25-39	18-30	40 to 50

What may, however, be the only proper system of management for a never-dying proprietor like the State,—the only landowner whose tenure need never terminate, nor be subject to the demands of death and estate-duties, &c.,—is not necessarily the most remunerative way of growing timber, and of reaping the advantages of woodlands, for the private landowner, who merely enjoys a life-interest in his estate. And the practical consequence of this is that the existing British woodlands have, in the vast majority of instances, been thinned more than would have been the case if the intention had been merely to grow timber on purely business principles.

A better System.—If owners of woodlands at any given time absolutely require returns from immature crops of timber which they intend should be managed on business principles, it would be preferable to calculate how many acres of any particular wood or plantation are necessary for furnishing the money or timber required, and to clear-fell the same to that extent, replanting it as soon as convenient. This seems better policy than the present haphazard system of promiscuous and heavy "thinning," by means of which the future value of the crop is usually diminished, while the danger of windfall is very much increased.

Marking Stems in Thinning.—Poles and trees to be thinned should be marked by the forester himself while they are in full leaf. It is best to fell and remove the marked stems during winter, after the falls of mature timber have been made; but the thinning can quite well take place in summer, if more convenient.

Fig. 65.



Different forms of the "Scribe" (single and double marking), with knuckle-guard.

The best way of marking the stems is with the **Scribe** (Fig. 65), which cuts off a clean strip of bark and sapwood, and leaves it hanging on the stem, to be more readily visible to the woodman later on, when felling. For small poles the single mark is more convenient, while the double mark is put on larger stems.

Before marking any pole or stem for removal, the forester should examine it carefully from all sides, to convince himself that its extraction will really be to the benefit of the neighbouring trees; and all scribe-marks should face the same way, so as to be readily seen by the woodman.

In mixed forests thinning is greatly simplified when the different trees are mixed in patches, according to the varying soil and situation. To what extent the softwoods should be thinned out depends on the crop.

When mature trees are felled, the life-history of the stem may often be plainly read from a section of the trunk. After each time of thinning there is a distinct increase in the breadth of the annual rings (Fig. 66). While the young trees are competing keenly

Fig. 66.

for food-supplies, light, and air, the annual rings decrease in proportion to the limitation of the growing-space. But when this struggle is ended by thinning, the annual rings at once broaden, and the increment (though confined to a smaller number of trees) is often considerably greater than it was before the thinning.

When once natural woods or plantations have got beyond their most energetic period of growth, varying from about twenty to fifty years of age with different trees, the necessity for thinning gradually decreases. In woods that have passed into or beyond the middle-aged period of their life, the need for thinning here and there is often indicated (especially in Oak and Beech woods) by the stem beginning to throw out a flush of adventitious shoots far below the proper crown of foliage. The nutrient reserves are apparently thus utilised in an effort to maintain and stimulate the energy of growth; and this is of itself an indication that such trees should be thinned out.

It is often, however, desirable to go much further than that in the way of removing trees to promote the more rapid thickening in girth of all the better stems during the last ten to twenty or more years (in Oak, Beech, and Silver Fir, of course, much longer than with other trees), and with this specific object in view, a *partial clearance* of the maturing crop may be made. This is a method that is not likely to be much practised in Britain, where plantations made for profit will mostly consist of Larch, Firs, and Pine, which often, in Britain, begin to show unmistakable signs of approaching maturity at forty to fifty years of age. At fifty years of age there ought usually to be found in British woods, unless heavily thinned, an average stock per acre (rough estimate only, for average soil and situation), of probably about—

Kind of tree.	No. of trees per acre.	Mean average at about 50 years of age.					
		Growing-space per tree.	Distance from stem to stem.	Cubic contents of crop per acre (square-of-quarter-girth measure).			
				Timber.	Lop and top.	Total.	Value about—
		sq. ft.	feet.	cub. ft.	cub. ft.	cub. ft.	£
Oak	about 300	145	12	1800	700	2500	100
Larch	400-600	72-109	8½-10½	2500	500	3000	120
Scots Pine				2500	500	3000	65
Beech				2400	1100	3500	60
Douglas Fir				4000	1000	6500	150
Spruce, Silver Fir	500-700	62-87	8-9⅓	2700	1300	4000	60

3. **A Partial Clearance to improve the main Crop**[1] is made in a high-wood when over 15 per cent of the basal area of the stems (usually including about one-fifth or more of the whole number of young trees forming the crop) is removed for the purpose of stimulating the rate of growth in girth after the main growth in height has been completed.

The removal of up to 15 per cent of the total basal area, measured at breast-height of the stems forming a crop in close canopy, is still a thinning; but beyond that it removes prematurely many of the dominant class of trees, and amounts to a partial clearance for the special benefit of the picked trees left standing.

[1] Further details than can here be conveniently given regarding the theoretical principles underlying Partial Clearance and Underplanting will be found in *Studies in Forestry*, chaps. ix. to xi.

In Britain this method is not practised at all as yet, and even on the Continent it is mostly confined to Oak, Scots Pine, and Larch, because the other light-demanding trees—Ash, Maple, Sycamore, Elm, Birch, &c.—are generally removed during thinnings and when the woods are between forty and sixty years of age. When Silver Fir or Beech are naturally regenerated, the same rapid increase in girth and improvement in the bole takes place during the clearances made before and after the seed-felling, and in sheltered localities not exposed to windfall it is also profitable with Spruce. The German system is as follows:—

When the first partial clearance is made—in Oak-woods about the fiftieth to sixtieth year, in Scots Pine between the thirtieth to fiftieth year, and in Larch about the thirtieth to thirty-fifth year—the fall is confined to stems of inferior growth, or such as do not give promise of ultimately producing first-class timber. About five, or ten, or fifteen years later, when the standard trees gradually begin to form canopy, the clearance has to be repeated, in order that the foliage on the lower branches and within the interior of the crowns may not be hindered in its assimilative functions owing to the decreased exposure to light and air to which they must be reduced in anything like close canopy. As in regard to thinnings, there can be no hard-and-fast rules for the conduct of partial clearances, for so much depends on the quality of soil and situation. But, practically, they should be repeated at intervals of about five to ten years at first, and about ten to fifteen years later on. **Oak-woods** treated in this manner about the fiftieth to sixtieth year should, according to Gayer, increase annually by from 3 to 3½ per cent in cubic contents up to their 100th year, and 2 to 2½ per cent after that, without taking into consideration the improvement in quality and market value. . . . When pure forests of Oak have passed through the regular processes of thinning, and approach the time for a partial clearance taking place, their canopy is in general somewhat light and thin, although perhaps not broken; and natural undergrowth is usually already beginning to form canopy for itself below the older crop. To avoid the formation of twigs and shoots from the dormant buds along the stem, often leading to "*stag-headedness*," the partial clearance should not be made by one fall, but is better attained by one or two heavy thinnings conducted to the extent deemed advisable for each individual crop. The time at which it should take place is also dependent on the special circumstances of each crop, special regard being given to the time of under-planting and the development of the undergrowth, the energy of growth of the trees, and the nature of the soil and situation. As, however, the efficacy of this method of treatment is all the more apparent the earlier it can be begun, the thinnings should, if possible, be commenced about the fortieth to sixtieth year. They should at first be confined to the young stems of backward growth, and to such as are never likely to attain good marketable shape. The oftener the thinnings can be repeated at short intervals the better, as any sudden exposure of the boles should be carefully avoided.

About ten or fifteen years after these preliminary operations have been begun, the main partial clearance will in most cases seem advisable; for by that time the crop should be in a state of active increment, due to the favourable influences of the undergrowth and the previous thinnings. Here, again, as also whenever further partial clearances are considered necessary later on, the fall is in the first instance confined to trees that have been damaged by organic or inorganic agencies, or that do not continue to yield satisfactory increment; and not until all such unremunerative material has been removed should any sound trees in energetic growth be cut out.

When the main partial clearance has taken place about the seventieth year, and has been followed by minor gradual clearances at intervals of five years at first, then of ten, and later on of fifteen, the preliminary yield or intermediate returns thus obtained should amount, according to Kraft (*Aus dem Walde*, vol. ix., p. 80), respectively to about 288 to 628 cubic ft., then to 720 to 1080 cubic ft., and ultimately to 1800 cubic ft. per acre, inclusive of branch-wood. Past experience seems, according to Gayer (*Waldbau*, p. 574), to justify the hope that by this method of treatment the same dimensions of bole can be attained in about 120 years as are obtainable in pure forests worked with a rotation of 200 to 240 years, provided that up till about the hundredth year the rate of increment has been maintained at 3 to 3½ per cent, and after that at 2 to 2½ per cent—conditions which are quite conformable with the actual results obtained on suitable soil. The crop of Oak

Fig. 67.

Scots Pine highwood, with Spruce underwood (Forêt de Bertrichamps, Meurthe-et-Moselle).

then ultimately harvested numbers about 36 to 48 trees per acre, which on good soil yield valuable timber. Where soil and situation are good enough to fulfil the demands made on them, there can be little doubt that this system of underplanting with a shade-bearing species, and partially clearing the main crop from time to time, is the method best calculated to produce timber of the highest value for technical purposes, and to yield the most favourable returns financially from the capital represented by the soil, together with the growing crop. . . . **Larch crops** partially cleared from the thirtieth to thirty-fifth year onwards should, on situations naturally adapted for their growth, at sixty to seventy years of age contain about 60 to 70 trees per acre with an annual increment of from 3 to 4 per cent. In **Scots Pine woods** a repetition of the process is only advisable on good soil, because, otherwise, experience has shown that better results can generally be obtained by letting the whole of the standard trees come together to form the light canopy usual on inferior soil and situation, and beneath which an underwood can usually thrive fairly well. **In mixed woods of Spruce, Silver Fir, and Beech** good results have been attained by beginning to thin rather heavily about the thirtieth year, repeating the thinnings every tenth year, and then making a partial clearance between the sixtieth to seventieth year, so as to leave about 120 to 160 well-grown trees per acre. In crops thus treated, after the lapse of twenty years spontaneous natural regeneration will generally be found to have been effected, the standard trees will be of good marketable size and quality, and the seedling growth will vary from about 3 to 15 ft. in height. Blanks left by the removal of the standards can easily be advantageously filled by planting Pine, Oak, Larch, Ash, Maple, &c.

Of course, an essential condition for the success of this measure is that the crops are still capable of being stimulated to increased rate of growth. The operation would be useless in the case of trees already entering (even prematurely, from injudicious treatment or any other cause) into the stage of senile decay. . . . Practical experience in Germany has shown that this method of partial clearance should, under ordinary circumstances, only be adopted on good soil and when undergrowth can be formed either naturally or without much outlay (*Studies in Forestry*, pp. 197 and 224).

The advantages of this method are that—

1. Larger and finer timber can be produced in shorter time, and therefore more cheaply.
2. Instead of a thick crop, with small annual increment spread over a large number of trees, (1) valuable thinnings can be realised; (2) the increase in the rate of growth on the remaining trees equals, and often exceeds, that of the thicker crop previous to partial clearance; and (3) the undergrowth formed naturally or artificially is often practically as good as a young crop formed by sowing or planting.

But, except when woods are undergoing natural regeneration, this method of treatment cannot be adopted with light-demanding trees unless the maturing crop is at the same time *underplanted*, to protect the soil from deteriorating. And even then it can only be profitable when the crops are still in sufficiently vigorous growth to be able to respond to the stimulus of more growing-space and sunlight (Fig. 67).

The rapid increase in growth thus effected (specially called *Lichtungszuwachs* or "free-exposure increment") is explainable as follows :—

Various causes have been assigned to the effects produced in enhanced increment after partial clearance. Th. Hartig considered it to be due rather to the utilisation of reserves of productive matter collected and stored up in the stem whilst it stood in close canopy, than to any increased assimilation in direct consequence of the increase in foliage that takes place when the individual tree obtains a larger growing-space; whilst Nördlinger, on the other hand, ascribed the enhancement in increment to the increase in the foliage, but laid particular stress upon what he considered the fact, that the enhancement was not so much the direct result of the increase in the mass of foliage as of the stimulated assimilative activity of the leaves and needles, with simultaneous temporary increase in the productivity of the soil, owing to the more rapid humification of the dead leaves on the ground.

The correct explanation as to the enhanced increment is probably to be found in a combination of these views. It seems much more than probable that the utilisation of the reserves of productive matter (principally starch in various forms) is most likely greatly favoured by the more active assimilation of nutrients whenever the increase in the foliage takes place; and there is no reason why this should not be directly connected with the formation of the fuller crown of foliage immediately after the partial clearance has been made. It is still an open question how such reserves of nutrients are formed, how they circulate throughout the tree, and how they are finally utilised, although their existence in the parenchym-cells of woody-fibrous plants is just as well known as that of similar reserves in orchids, perennial tuberous plants, &c. The destruction of forests in Bavaria during 1890-92 by the Nun moth gave Prof. R. Hartig of Munich special opportunities for studying a part of this subject, particularly with regard to Spruce; and he conclusively proved that this species of tree has much fewer reserve supplies of nutrients than Scots Pine. In general, as is well known, such reserve supplies are far more plentiful in the broad-leaved deciduous species of trees than in Conifers, and larger in the deciduous Larch than in the evergreen Conifers. All the changes that take place in trees prior to the commencement of the assimilative activity in spring are ascribable to these nutrient reserves—the flowering of Hazel, Alder, and Willow, the swelling of the buds, and the flushing of the young leaves, the formation of rootlets, &c. In fact, all the similar phenomena previous to the development of independent cambial activity must be ascribed to these reserve supplies of starchy and nitrogenous nutrients. The supply of reserves is usually sufficient to maintain vegetation for one complete year, and often for longer; indeed, in many cases it amounts to 7 or 8 per cent of the total weight of thirty-year-old timber crops. Diminution of light and foliage, consequent on limitation of growing-space, must interfere with the utilisation of these reserve nutrients; hence it is quite logical and reasonable to expect that with more growing-space, and a consequent increase of foliage, these reserves should be largely drawn upon and utilised.

That any increase in soil-productivity takes place through aeration and better formation of humus is doubtful, or even more than doubtful; for, unless the canopy still remains comparatively close, the soil soon becomes covered with weeds, which often consume the mould and exhaust the soil, in place of the timber-crop having the full benefit of the humus.

The true physiological cause of the improved increment after heavy thinnings or partial clearance in crops approaching maturity is to be found in the more rapid formation of starchy matter through insolation; for the activity of assimilation in the foliage depends on the purity or brilliancy of the rays of light, as decomposition of atmospheric carbonic acid can only take place when the waves of light attain a certain length. While a crop is growing in full canopy, the assimilative activity of the foliage forming the lower portion of the crown is extremely small, owing to the low quality of the diffused light which is alone available; but when the canopy is opened up to a sufficient extent, these portions of the lower foliage, which have been practically inactive, or may perhaps even have been existing on the work done by the upper leaves or needles, reassume their normal assimilative functions and help to enhance the general increment of the tree. And, besides this increased assimilative power of the foliage, the consequent increased formation of new leaves and needles is undoubtedly of enormous influence in maintaining and increasing the general enhancement of increment throughout the stem. As remarked by König, the direct result of the freer exposure to light and warmth leads to the better and more energetic development of the leading-shoots, the strengthening of twigs, and the formation of twigs from buds that would otherwise most probably have remained dormant.

The enhanced increment continues until the crop once more forms close canopy. But, if it be again stimulated by a repetition of the thinning out or partial clearance, this may—if not accompanied by underplanting—be carried so far as to involve deterioration of the soil to such an extent that the beneficial influence of light and warmth on the crown is cancelled by the diminished activity of the root-system, consequently involving decreased supplies of moisture and of mineral nutrients for conveyance to the assimilative organs. (*Studies in Forestry*, p. 215.)

Fig. 68.

An English Oak-wood, 45–47 *years of age* (*Tring Park, Herts*, 1900).

The trees average 37 ft. in height, and about 16 cub. ft. in contents, exclusive of tops. About this age it would, in Germany, prove profitable to underplant with Beech, to protect the soil.

In mixed woods of Oak and Beech this method may be quite practicable in Britain if a local market demand exists for Beech of small girth before it has lost the power of throwing out stool-shoots—but that will seldom be the case. And to form artificial undergrowth by sowing or planting will still more seldom prove profitable. There may, however, be more or less of natural underwood like Ash, Sycamore, Chestnut, Hazel, Holly, &c., and protection for game may induce the owner to go the length of planting Spruce or Silver Fir in patches here and there, as well as shrubs like Privet, Rhododendron, Dogwood, Buckthorn, &c. All of these help to protect the soil, though of course they are not so beneficial as Beech or Hornbeam, which are usually quite out of the question in Britain owing to the poor demand for small material. Without some such artificial assistance, however, the ground would usually become covered with rank weeds like blackberries, bracken, &c., which are often hard enough to keep down in any case (Fig. 68).

Pruning of Trees.—Opinions vary as to the desirability of pruning; but it is sometimes advisable, and especially in copse-wood standards. When any branch of a tree is cut off, there must of course be some disturbance in the balance between imbibition by the roots and assimilation in the foliage; but this need not necessarily amount to a serious disturbance of the vegetative process. Pruning may sometimes, therefore, like **thinning**, improve the growth of the timber-crop.

Both **Thinning** and **Pruning** are done to assist and hasten the more gradual work of nature. Just as in crowded crops the less energetic stems are dominated and finally suppressed through want of light, so also the lower and inside branches of tree-crowns divert some of the sap in its upward course and there assimilate it in a less thorough manner than if it were elaborated only by foliage in full sunlight. By eliminating superfluous lower branches, the sap is utilised chiefly by the upper portion of the tree, and a relatively smaller proportion of it finds its way down to the base of the stem, so that the annual rings become relatively broader at the top of the trunk than at the butt-end. This makes the stem more valuable, because its technical and market value very often depends on the size of square that can be obtained. A full-wooded 40-ft. trunk having a top-diameter of 27 in., with a butt-diameter of 33 in., would be far more useful than a stem of equal length having a diameter of 36 in. at the base, and only 24 in. at top, although both would contain about the same number of cubic feet of wood.

In highwoods that have not been over-thinned pruning is not required, because in close canopy the trees clean themselves of unnecessary branches. It is only needed to correct past errors, and even then pruning can only be profitable on a valuable kind of tree like Oak.

The mere cleaning of the stems by removing dead branches does not interfere in any way with the growth of the tree, and is useful in preventing the formation of hard knots. But it is otherwise with live branches.

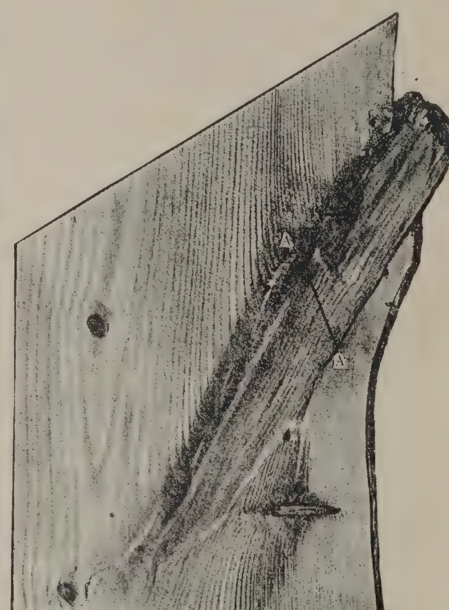
The removal of living branches is a direct interference with the vital condition of the growing tree, and can therefore only be ventured on to a limited extent. Under no circumstances should more than one-third of the total quantity of foliage be removed at one time; practically, only about one-fifth of the foliage is generally the extent removed during such operations. Experience has shown that, even in the case of quick-growing kinds of trees, the removal of living branches should ordinarily be confined to those that are not over 2½ inches diameter for Conifers, or not over 4 in. for broad-leaved species of trees, as, otherwise, the process of cicatrisation cannot take place quickly enough to ensure hindrance of the germination of fungous spores producing disease.

As the broad-leaved species of trees are not so liable as Conifers to fungous infection, they usually stand trimming better. . . .

The trees which best stand the removal of green branches are the Oak, Silver Fir, Larch, and Pines, when they are in energetic growth on favourable soil and situation, and have normally developed crowns. Ash, too, can well bear the operation ; but, as Ash and Alder both grow with naturally clean stems, pruning is hardly required in their case. Whenever the removal of branches takes place to any great extent from Oak, Maple, Sycamore, or Elm, the result is that the bole has a tendency to become covered with shoots from dormant buds. This, of course, considerably diminishes the value of the stem, besides, particularly in the case of the Oak, exposing the tree to the danger of becoming "*stag-headed*" or dead in the upper portion of the crown. The softwoods—Birch, Willows, and Poplars—are not naturally adapted for this kind of treatment, owing to the comparatively slight resistance which their soft porous wood is able to offer to fungous disease ; hence any wound-surfaces formed afford only too favourable a germinating-bed for the disease-producing spores.

Fig. 69.

Fig. 70.



To diminish danger from fungous disease, the wounds should be coated over with some antiseptic substance impervious to moisture. In Conifers this takes place naturally by the oozing out of resin ; but some coating must be provided artificially in the case of broad-leaved trees. Tree-wax, formerly much used abroad for this purpose, consisted of a mixture of 1·20 parts (by weight) of bees-wax, 2·70 pure resin, 0·60 turpentine, 0·15 wood-oil, and 0·15 suet, all dissolved in warm methylated spirits. A simple coating of coal-tar, slightly thinned with paraffin or turpentine, is, however, equally effective. As the coating of tar will only bite into the surface satisfactorily while the wood is fairly free from sap, it should be applied either towards the end of October, immediately after the fall of the leaf, or else during the first half of winter. Unless pruning takes place in autumn or early in winter, the experiments made by Prof. R. Hartig of Munich show that, in addition to the tar not obtaining a good hold on the wound-surface, the condition of the woody tissue is such as to make it less able to resist the penetration of disease-producing fungous spores. Practically, the same principle holds good here as in thinning young woods; it is better to prune to a moderate extent only, and afterwards repeat the operation if necessary, than to try and effect the object in view by one heavy cutting. (*Studies in Forestry*, p. 205.)

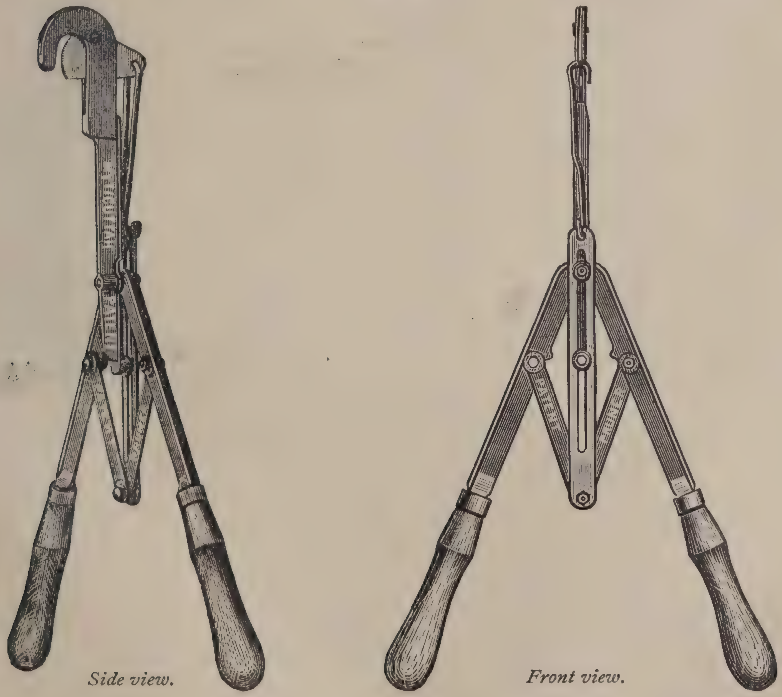
The practical benefits of pruning living branches and removing dead ones may be seen in Figs. 69 and 70. The former of these shows the completely cicatrised wound-surface of an Oak, and the latter the dead branch of a Conifer, which should have been pruned about thirty years previously at AA.

Fig. 71.

Pruning Implements.—Besides the **pruning-shears** (Figs. on p. 383), the common **pruning-knife** (Fig. 71) is generally used for pruning branches that can be reached from the ground, and are not more than 1 in. diameter. It is not made with a hinge like a pocket-knife; but the blade is fixed into the handle, and is straight in the face, without any hook at the point like a garden-knife. When not in use, it is carried in a leather sheath at the side. It should be kept very sharp, so as to make a smooth upward cut close to the stem.

For the pruning of strong poles or trees whose branches are within a man's reach, but are too large for being easily cut off by the pruning-knife, the **Myticuttah** (Fig. 72; Standard Manufacturing Co., Derby) may be used. It consists of a strong steel hook, which is placed over the branch to hold it steady whilst it is pruned by the cutting-blade working within the hook. By pressing the lever handle steadily a smooth even cut is obtained without having bruised the bark. It is convenient

Fig. 72.



Side view. *Front view.*

for trimming Holly and Thorn hedges, shrubs, and prickly bushes, in cutting which, even with gloves on, it is difficult to keep the hands and wrists from getting torn.

The **Pruning-saw** may also be used (Fig. 73, *a*). This has a movable blade adjustable to any angle by means of a screw-handle, while the saw can also be loosened or tightened. In using it care should, first of all, be taken to make a slight cut on the lower side, say from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch deep if the branch be 3 in. diameter, to prevent the latter, when

Fig. 73.

Different Pruning Instruments.

a, Pruning-saw; *b*, Pruning-chisel; *c to g*, Aerial Combination; *h*, *i*, Tree-pruner; *j*, Averuncator.

nearly cut through, from tearing away the bark as it falls, and thus opening a wide entrance for disease-producing fungous spores. The rough wound-surface should also be pared and smoothed with a sharp knife, and coated with tar to prevent rain-water lodging on the wound, and to diminish the risk of fungous infection. Or 1 gill paraffin to ½ gallon coal-tar also forms a good antiseptic coating.

Another useful instrument is the **Pruning-chisel** (Fig. 73, *b*), the well-seasoned Ash-wood handle of which may be of any convenient length, and shod at the end with an iron ferrule or ring. The pole is held with the left hand, and the face of the chisel is put to the base of the branch. One or more strokes are then given with a mallet by the right hand on the iron-shod end. This forces the chisel through the branch and separates it from the stem. Care should be taken to repeat the strokes lightly when the branch is nearly cut through, otherwise the chisel may slip too far through and injure the bark of the tree. When parts of very long branches are to be shortened, the knife-edged hooked parts below the chisel are used. They are kept sharp on the inside, so as to make a clean cut when suddenly jerked down after being put in proper position. A fairly large branch may be cut through very quickly, and in the hands of an experienced woodman this is a very effective instrument.

Other useful pruning instruments are also made by the Standard Co., Derby. The **Aerial Combination** combines an improved form of pruning-chisel with a pruning-hook and three different kinds of pole-saws (Fig. 73, *c* to *g*), and the common **Tree-pruner** (Fig. 73, *h*, *i*) consists of a pole, hook, metal rod, lever, and blade. The steel-hook is double, and the knife working *in* the hook is thus supported on both sides, and can be made very thin, to reduce the resistance of the wood and make a clean smooth cut. The knife is connected with and worked by a metal rod giving leverage, whilst the branch, encircled by the hook, cannot escape until the portion to be removed is severed. The whole is very light and easily worked, and it can be had with any length of pole. The **Giant Tree-pruner** is a similar but more powerful implement, worked by a lever with ratchet and clutch.

The **Averuncator**, Fig. 73, *j* (Messrs Saynor, Cook, & Ridal, Sheffield), consists of shears worked on the end of a pole by means of a lever-handle to which a cord is attached for pulling the handle in the act of cutting through the twig. The pole may be of any convenient length, so that twigs and small branches can be cut off to a height of 25 or 30 ft.

Various other similar implements are known under such specific names as the **Standard Tree-pruner**, or the **Parrot's Beak**, &c., which vary in price and effectiveness; but though all such handy tools may be the most convenient to use for pruning small branches, yet when it comes to real hard work the hand-saw has generally to be used. The cleanest and most knife-like cut is given when each alternate pair of teeth is bevelled on the inner edge, the bevel on each tooth being in the reverse direction from that on the other twin-tooth, because this forms a sort of plane-like cutting edge at each forward and backward movement of the saw (Dittmar's patent), thus—

CHAPTER VI.

THE RENEWAL OF WOODLAND CROPS.

REPRODUCTION OF COPPICES AND COPSE-WOODS, AND REGENERATION OF HIGHWOODS.

When any woodland crop has reached the age or size at which the fall is intended to be made, it may be renewed either by being *artificially reproduced* or *naturally regenerated*. In the former case, in *coppices* and *copse-woods* the roots of the mature crop throw out stool-shoots or suckers which grow up into a new crop; while in the latter, in *highwoods* or *timber-crops*, the mature trees are, when felled, replaced by a young stock of plants raised from seed. This young crop may either be formed from seed shed naturally by the mature trees before their clearance, or blown across from adjoining areas, or scattered over the area artificially by sowing; or else it may be planted with young plants taken from the woods, or specially grown in nurseries for this purpose.

The opinion has often been expressed in Britain that there should be a change of tree when mature crops of timber are harvested. In natural woods crop succeeds crop; and when changes take place, they can easily be accounted for by the relation of the different species towards light and shade, frost, &c., or by the power of the seeds of certain light-winged species to lie dormant (like Birch) for many years, and at length germinate whenever they have favourable supplies of light. The researches of sylvicultural chemists — Ebermayer, Wollny, Ramann, and others—prove that there is no danger whatever of any high-timber crop exhausting any given mineral food, so long as the crop is grown in close canopy to protect the soil against sun and wind, and so long as the dead foliage is retained to form *humus*.

Evergreen coniferous crops in particular, if properly managed, leave the land much richer in soluble nutrients than when the area was originally planted with trees; and soil which has been allowed to become temporarily exhausted by badly managed broad-leaved crops may be recuperated by one crop of evergreen Conifers, so as to become suitable once more for the growth of deciduous trees. Mismanagement or disease may sometimes necessitate a change of crop; but this has nothing to do with the demand of trees for one particular kind of food in greater quantity than a properly protected soil can yield.

In the natural Pine woods of Strathspey and Braemar, crop has succeeded crop from time immemorial, yet they produce stems as good as any found lying in the mosses, the remains of crops grown centuries ago. And whenever parts are sufficiently clear of old trees, a crop of young and healthy seedlings soon rises up thickly all over the ground. The only two necessary conditions are that the tree (or trees) should be suited to the soil and situation, and that fairly close canopy be always maintained.

The **advantages** of natural regeneration are—

1. The crop can be formed with comparatively small outlay for soil-preparation.
2. The crop is generally thicker, and therefore forms canopy sooner, thus protecting the soil better than when formed by sowing or planting.
3. There is little danger of the crop not being suited to the soil.
4. It affords good protection against drought, frost, insects, and fungous diseases.

The **disadvantages** are—

1. The time of regeneration depends on good seed-years, which cannot always be relied on, so that the regularity of the annual falls and other provisions of the working-plan may be interfered with to a greater or less extent.
2. More supervision and technical knowledge are required than for sowing or planting.
3. The young crops are usually somewhat irregular.
4. It is only really cheaper than sowing or planting when the operation is successful, but not when there are many blanks to fill up.

In all extensive woods natural regeneration has many practical advantages. On the whole, it costs less than sowing or planting, and any such difference in first cost means a good sum when calculated for 50 to 70 or 100 years at compound interest. The young plants are better protected against drought, frost, insects, and fungous diseases, and the soil is not so likely to become overgrown with rank weeds or to lose in productivity as when the whole surface is laid bare to the full action of sun, rain, and wind. The young crop is generally denser, and the thickets grow up clean and close ; but early thinning is necessary to prevent the young poles being drawn up too lank from overcrowding, as the struggle for existence is more severe and longer than in plantations. It may be argued, and with truth, that during the early years of growth loss of increment is sustained which can be avoided by raising plants in nurseries and transplanting them at one, two, three, or more years of age. But it should not be overlooked that the partial clearances made in the mature crop to stimulate production of seed and prepare the soil for its reception usually cause a larger increment to take place on the parent stems than if the whole crop were left standing until clear-felled for planting. And that such is the case is a matter of common experience throughout Germany. At the same time, good opportunities are also given for planting patches of valuable trees (Oak, Ash, Larch, &c.) here and there to form mixed woods.

1. **Coppice and Copse-woods.**—Coppicing is the simplest way of reproducing a woodland crop ; and the more clay there is in the soil, the greater the reproductive power usually is. By cutting as close as possible to the ground a better flush of stool-shoots and of suckers is obtained, and the stools last much longer than when high stumps are left. Where the stools are worn out or stand too thin, the best and cheapest way of improving the crop is to *layer* or "*plash*," an old English method still commonly practised all over the southern counties. When felling the coppice, as many small shoots as are needed, from the thickness of a thumb up to about the thickness of a wrist,

are cut only half through close to the ground, then bent down into a prepared groove, pegged into position with a branch-crook, and covered with the sods of turf and earth taken up. It succeeds best with strongly reproductive trees like Chestnut, Ash, Elm, Lime, &c. The formation of shoots along the buried sapling is stimulated by making longitudinal cuts here and there through the bark, or by giving the shoot a sharp twist with both hands, as the physiological disturbance thus caused seems to hasten and to increase the effort towards independent life and reproduction. To be effective, plashing must be done in the autumn or winter immediately after the fall of the coppice, *before the stools have flushed their new shoots*, else the sap naturally gets drawn to these as soon as their leaves are formed.

In Southern England *plashing* became almost a lost art, surviving only in hedgerows. But at one time it was habitually practised in copse-woods, as is well described in Stevenson's *Agriculture of Surrey* (1813, p. 416):—

"*Copse-woods.*—These consist principally of the Oak, Birch, Ash, Chestnut, Sallow, Hazel, and Alder. As it is the usual practice of the woodmen of the Weald of Surrey to look entirely to seedlings for a supply of timber, the sapling shoots from the stools are the principal source of copse-wood. After a fall of timber, these saplings are preserved and taken care of, and thus the undergrowth is continually increasing, and the demand for copse-wood regularly supplied. It is plain that if the stools of the fallen timber had but common justice done to them in protecting them from cattle, and draining the adjoining ground, a most ample supply would be obtained from every part of the Weald. But though this judicious mode is followed in many parts, yet a very slight inspection of the underwoods will convince any one that it is not nearly as general as it ought to be. Proper care and attention, especially to keeping the soil dry, will go a great way to ensure a full and regular supply of copse-wood; but as even under the most judicious and attentive management a partial failure will sometimes happen, it is proper to mention a method which has been found by many proprietors of woods in Surrey effectually to answer the purpose of supplying such failures.

"It is simply by **plashing** the shoots where a vacancy appears. This is done by cutting the shoot about half through with a bill: the shoot thus cut is laid along the ground; at each of the joints a cut in the direction of the bough is made, over which a little fine mould and turf are laid; the shoot is kept close to the ground by means of pegs. At each point the shoot that is plashed will take root and throw out several saplings. As soon as the shoot that has been plashed appears to have taken sufficient root in each of its points (which generally happens in two or three years), it is entirely separated from the parent stool: after this is done, the shoot itself is divided in every point where it has taken root, and thus several stout and flourishing saplings are procured from one shoot, which are found to thrive better than the shoots managed in the usual manner, and to be less hazardous than fresh-planted trees.

"It is not, however, only in the direct advantage of this mode that its superiority consists: it is plain that whoever adopts it must pay more than the usual attention to keep the ground clean and dry, otherwise the shoots thus managed would be overpowered and destroyed before they had taken sufficient root. As holding out the necessity of working the ground, therefore, this mode should be recommended and adopted, even though the direct advantages derived from it were less certain and important than they actually are. . . ."

Alder is coppiced in the usual manner, but the height of the stool depends on the height to which the soil may be inundated. If floods are not probable, felling should be close to the ground; but if the soil is likely to be submerged about the time of the shoots being flushed, then stools of 12-18 in. high must be left, as even a few days' submersion is apt to kill the shoots. Where blanks are filled with transplants that have not been cut over above the roots before being planted, it is best to let them grow uncoppiced for the first period of rotation.

In *Osier-holts* the stocks must be cut close to where the shoots have sprung, otherwise the stools will enlarge and the crop of rods decrease both in number and quality. Sometimes the stocks are pared to keep them of small size and in vigorous reproduction. On good stools the rods grow 6-7 ft. long, and sometimes even 8-9 ft., during the season. After being cropped, the holts should be dug between the lines to aerate and weather the soil.

The *Felling of Coppice* should be done by the owner's own workmen, as this is more likely to ensure good work than if the crop be sold in hags standing. The cut should be made as low down as possible with a bill or axe, and should be clean and slanting to prevent water lodging and rot setting in (Fig. 74). This is much better than the use of a saw, as the flat rough-

Fig. 74.

Fig. 75.

Fig. 75*a*.

Fig. 76.

sawn surface (Fig. 75) holds water, and fewer stool-shoots are produced. The worst method of all is when two cuts are made from opposite sides, leaving a wedge-shaped depression to catch water and induce rot (Fig. 75*a*). Care should, of course, be taken to prevent splitting of the stool.

A long, well balanced, **heavy bill**, with a slightly curved blade about 18 in. long and ½ an inch thick at the back, firmly fixed in a rounded wooden handle 9 or 10 in. long and slightly bulging in the middle to give a firmer grip, is a very effective and clean-cutting instrument.

Trimming of stools with an adze is necessary when poles or young trees have been sawn through, to encourage the production of shoots (otherwise usually either wanting or few in number when the saw is used alone, especially in Oak); but it is expensive (Fig. 76).

The best time for coppicing depends on circumstances. In ordinary coppice it takes place whenever most convenient during autumn or winter,—though the later the fall, the less likely it is that the stools may get damaged by winter frost, or that young crops of shoots will suffer from late frost in spring. *Oak-bark coppices* can, of course, only be felled from the end of April till early in June, so long as the bark will strip. In *Osier-holts* the cutting usually begins in January; and in *Alder-groves* of a swampy character it is most convenient to fell during hard frost, when the poles can most easily be brought out while the ground is hard and firm.

Standards in copse-woods should be felled and removed immediately after the fall of the coppice, otherwise they are bound to damage the young crop afterwards. Oak standards should therefore be barked standing, if intended to be barked at all, during the spring before the fall of the coppice (a method common in Devonshire, and largely practised near Hildesheim, in Hanover).

2. **Highwoods** may be renewed by—

(1) **Clear-felling** or **Total Clearance** (*Kahlschlagbetrieb; Futaie régulière—Procédé par coupe unique*), the regeneration being either artificial (by sowing or planting), or else to a greater or less extent natural by seed blown over from contiguous woods lying to windward (in which case the fall has usually a long and

narrow shape); or only a very few trees may be left on the area as seed-bearers (Scots Pine).[1]

(2) **Successive Falls** or **Partial Clearances,** usually confined to definite periodic blocks, with natural regeneration from seed shed by the mature trees before all are finally removed from the area. The various successive falls or partial clearances made for this purpose may be—

(*a*) **Casual** or **Sporadic Fellings** made more or less regularly or irregularly, as to both periodicity of rotation and extent of fall, by removing mature or for any cause undesirable trees here and there throughout a whole wood (*Fehmelbetrieb*, *Plenterwirthschaft; Jardinage*, *Futaie jardinée*).[2]

(*b*) **Felling in Patches,** or **Natural Regeneration in Groups,** consisting in the simultaneous clearance of small patches throughout a whole block of woodland so as to form numerous small family groups of seedlings, the limits of which are gradually enlarged until the whole area is regenerated (*Fehmelschlagbetrieb*, Gayer's *horstweise Gruppenwirthschaft;* but in France it is comprised within *Futaie jardinée*).

(*c*) **Regular Partial Clearances,** or **Uniform Natural Regeneration,** consisting in making partial clearances uniformly over a whole block of woodland, good seed-years being utilised to produce, simultaneously, a more or less homogeneous young crop of seedlings over the whole block of woodland (*Schirmschlagbetrieb; Futaie régulière—Procédé par coupes successives*).

(1) **Clear-felling** or **Total Clearance** is the usual method in Britain, except in the remains of our natural Beech, Oak, and Scots Pine woods. Generally the whole of the mature crop is clear-felled, and the area cleaned and prepared for planting as soon as possible, except where conifer stumps are likely to attract the Pine-weevil, which would breed in these and then attack the young crop. Where this pest is to be feared, the stumps must either be grubbed or else replanting delayed till about the fourth year, when the dry stumps no longer attract the beetle. But as there will then be a heavy growth of rank weeds, clearing and burning the weeds and preparing the soil for planting becomes expensive.[3]

[1] In France this last method was ordered by the *Ordonnance de Forêts* of 1669 to be applied to all highwoods in certain districts, eight seed-bearers being left per acre. It is now practically confined to Pine-woods, and necessitates a good deal of artificial assistance.

[2] This method is called **Selection-felling** in India, but the term is misleading.

[3] The plan formerly adopted by many Scottish foresters, of allowing land to lie fallow for about four years after clearing the mature crop, was not believed in by all of them :—

"As already stated, Mr M'Corquodale (Scone Forests) does not consider it impossible to replant land from which a crop of timber has been recently removed, and does not agree with Mr Grant Thompson (Strathspey Forests) that it is necessary to wait until the natural herbage or vegetation returns; but he does consider that, in order to plant successfully, special treatment is necessary. He appears to have given the matter much attention, and has arrived at the conclusion that it is the beetle, and the beetle only, which interferes with the growth of young trees planted on land recently cleared of Conifers. He has contributed several papers on the subject to the Scottish Arboricultural Society, and tried various methods for overcoming the difficulty, arriving at last at the following, which he has now no hesitation in recommending: Allow the land to lie entirely waste for one year, excluding all cattle and sheep, in order to allow grass, &c., to grow. Then burn it when dry, and plant out by the double-notching system. This plan should not cost more than 15s. per acre, all told; and the saving by not allowing the land to lie waste for a number of years, as in Strathspey, is very considerable." (Campbell Walker, *Report on English and Scotch Forests*, 1872.)

The various steps to be taken in soil-preparation and in sowing or planting have already been described in chap. iii., and nothing need be added here save to remark that the more fertile the soil and the stronger the growth of weeds, the greater is the necessity for the use of strong transplants, because danger from frost is increased with a rank growth of weeds (owing to more rapid cooling by radiation during cloudless nights in spring).

A German development of the system of clear-felling with natural regeneration from mature crops to the windward has long been customary in parts of the Scots Pine sandy tracts in the north. Strips varying from about 35 to 100 ft. broad are made to alternate with older seed-bearing woods, the broad-side being at right angles to the prevailing wind. On parts with poor dry sandy soil, where extensive clearance would be injurious, the alternate strips are made 45 to 75 yards broad and the cleared parts are planted, as this is found to answer better on the very poor soil where natural regeneration is difficult and extensive clear-felling is always risky.

When natural regeneration of mixed woods is tried in this manner, the trees most likely to spring up are those producing large quantities of small, light, winged seeds, such as Birch, Poplar, Willow, Elm, Larch; then Pine, Spruce, Douglas Fir, Ash, Maple, and Sycamore; Lime, Hornbeam, Silver Fir; Beech; Chestnut and Oak. It is a method only suitable to Conifers, and Ash and Maple, but if softwoods are in the neighbourhood, there is always risk of their appearing in far larger number than is desirable, and their subsequent removal may prove troublesome. The young crop is generally unequal, while weeds and stool-shoots of softwoods, &c., often cause a lot of trouble, so that, on the whole, this method of natural regeneration is not to be recommended, though sometimes successful for Pine.

(2) **Successive Falls** or **Partial Clearances** are a method in which the young crop is raised from seed shed by trees forming the mature crop. The parent trees thus not only furnish the seed necessary, but also protect the young seedlings against heat, drought, frost, weeds, &c., until the young plants can either thrive independently of such overhead protection, or may even require the removal of the trees in order to obtain larger supplies of light, dew, &c.

Originally only the **Oak** was cultivated throughout England and the Scottish Lowlands; and later on the **Beech** in the natural woods on the Chalk-hills of Central and Southern England acquired commercial value (chair-making industry); while later still the **Scots Pine**-woods of the Scottish Highlands also attained marketable value and received attention. In all the English copse-woods the cultivation of other timber-trees, Ash, Elm, &c., was subordinate to that of Oak for shipbuilding (see *Introduction*, p. 17). So far, therefore, as anything like systematic treatment was concerned, Oak, Beech, and Scots Pine were, and indeed still are (with the Larch added), the chief timber-crops grown; and all three were originally, and to some extent still are, renewed by means of **natural regeneration**—*i.e.*, from seed self-sown over the whole woodland area by trees shortly before their removal as a mature crop.[1]

The first essential for this method of **natural regeneration** is, of course, that the crop of trees is capable of producing good germinable **seed.** Given this condition, the measures to be taken are partly determined by consideration of the **soil**, partly by that of the **young crop.**

[1] An interesting and instructive article on *Natural Regeneration in Britain* will be found in the *Trans. Eng. Arbor. Soc.*, vol. v., Part III., 1902-1903.

Soil.—The crowns of the trees, by overshadowing the soil, prevent its getting overheated or dried up by sun and wind. **The young seedlings** are at first protected against sun, wind, heavy rainfall, and late and early frost, until they thoroughly establish themselves and no longer need such protection, or until their natural requirements as to light, warmth, and dewfall render necessary the removal of the parent trees (*e.g.*, as soon takes place with Scots Pine on dry sandy soil). Next to the production of the necessary seed, the protection of seedlings against **frost** is one of the most important uses of the standard trees, because otherwise on clear wind-still nights the unhindered radiation of heat greatly increases the risk of late spring frost, which is so dangerous to young shoots and plants; while their other most important function is to prevent the growth of **weeds** to any extent likely to choke or interfere greatly with the young plants. At the same time they help to diminish danger from mice and voles, cockchafer grubs, beetles, and weevils, &c., and when the soil is fresh the dead leaves decompose sooner than otherwise, while earthworms in large numbers do much to improve the general condition of the soil.

The chief drawback, and often a very serious one, to natural regeneration in Great Britain and Ireland, is the general dampness of our climate and soil, because this causes a far richer, ranker growth of weeds than in the drier condition of soil and air usual on the Continent. There most weeds, except such as whortleberry, fail to assert themselves under a fair amount of overhead shade, and anything like the wild rank profusion of bracken, brambles, &c., which often springs up all over our woodlands whenever the canopy of a middle-aged or old wood becomes slightly broken, is unknown in France or Germany (see Fig. 27, p. 336, and Fig. 68, p. 453).

On *sandy soil* well-grown crops of Scots Pine can be easily regenerated naturally; but if the mature crop is not really of good growth, it is better to clear-fell and replant, as on dry sand the young seedlings are far too intolerant of shade to make natural regeneration a success.

On *clay soil* a good deal of soil-preparation is usually needed to promote the decomposition of the dead leaves on the ground. Natural regeneration is generally easy, as the seedlings can endure more shade here than elsewhere.

On *limy soil* seed-production and humification of dead foliage are both usually good. Little or no preparatory clearance is needed before the seed-fellings; and as the seed is usually of good quality and germinates well, seedlings come up freely and can endure overhead shade, so that natural regeneration is comparatively easy. But where sandy or limy soil is stony and easily heated, great care has to be taken in only gradually removing the overhead cover.

On *loamy soil* natural regeneration is easy in a good seed-year; but as such cannot be depended on to recur frequently, sowing is often necessary if sufficient seed is not produced after a seed-felling has been made, because the soil soon gets overrun by weeds.

(*a*) **Casual** or **Sporadic Fellings**, in which the falls are either made annually or at intervals of five or ten years, are the best way of dealing with woods of a more or less ornamental character. This method changes the general appearance of the wood least of all, provides the best protection against wind, and, with the assistance of planting, offers good opportunity for making picturesque mixtures of trees.

In extensive woods worked in this way considerable regularity may be attained by dividing the woods into five or ten blocks and going over one each year, to remove as much of the mature and the badly grown, unhealthy, or otherwise undesirable trees as may seem appropriate.

This casual or sporadic kind of treatment is the nearest approach to nature's method in virgin forests, but it is not the most profitable way of working woodlands. Many of the Beech-woods in Herts, Bucks, and Berks are worked more or less regularly on this plan, being divided into about ten or twelve blocks, within one or other of which a fall of timber is made annually. This is, of course, a system only applicable to shade-enduring trees, unless considerable assistance is given in the way of planting and tending (thinning).

(*b*) **Felling in Patches**, or **Natural Regeneration in Groups**, is a further improvement on the above natural process of replacing old dead trees in virgin forests. It consists in clearing small patches here and there all over the area to be regenerated, and then gradually extending these clearances as the patches of seedlings establish themselves. Two conditions are requisite for success—(1) the trees must be able to withstand heavy winds, and (2) the seedlings must be able to endure a good deal of shade. The method is therefore only used for Beech and Silver Fir, and for Spruce in sheltered localities ; but pure woods of Douglas Fir might also be thus treated.

This **Group method** is mainly confined to Silver Fir, where it forms the usual mode of regeneration in the Jura, Vosges, Black Forest, and Bavarian Alps. Say the whole woodland area is worked with a rotation of 120 years, and is divided into six blocks, then every twenty years one block would be taken in hand, and the regeneration would extend over twenty years.

The *futaie jardinée*, or formation of small family groups, has long been in use in Central and Western France, but in Germany it was first recommended by Gerwig (*Die Weisstanne in Schwarzwald*, 1868, p. 97) for Silver Fir in the Black Forest. He recommended the clearing of patches of 8 to 10 yards in diameter (or larger if the soil was dry) all over the area to be regenerated, and sowing seed on them, then gradually removing the trees to widen the diameter of the patches till the whole of the mature timber has been cleared. The *modus operandi* will be easily understood from Fig. 77.

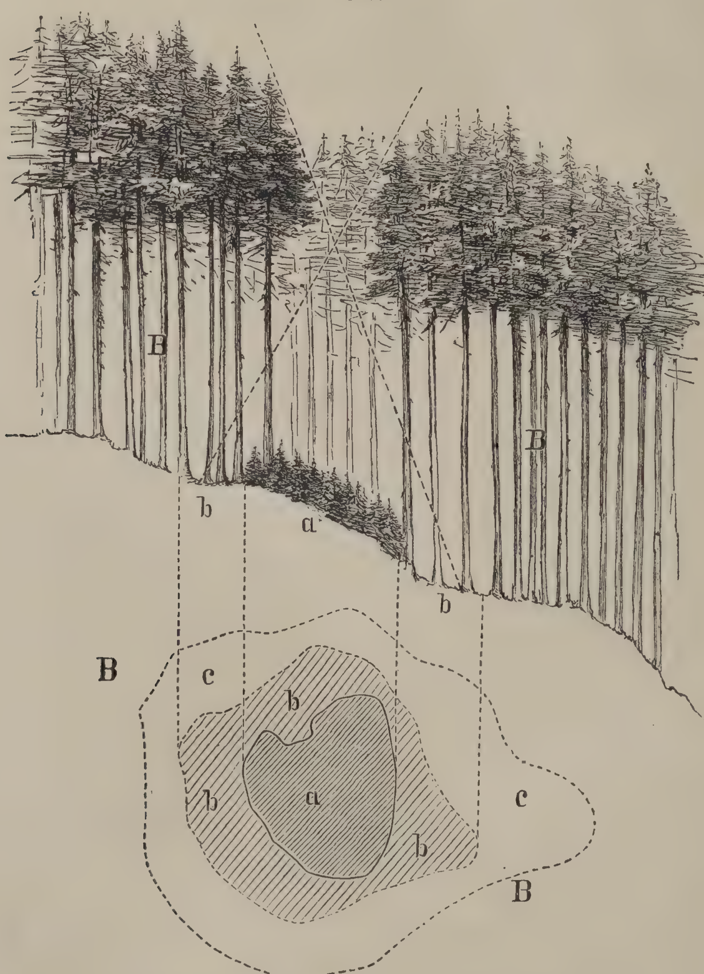
(*c*) **Regular Partial Clearances** or **Uniform Natural Regeneration** throughout a whole block of woodland is the usual method of regenerating Oak and Beech woods in France and Germany, and is also extensively applied to Scots Pine ; and it is more or less (though not quite so systematically) the system applied to Oak, Beech, and Pine in Britain. But in its entirety it is here only really suitable for the shade-enduring Beech.

In this method, as practised in France and Germany, three different kinds of partial clearance are made in the mature crop—

1. **A Preparatory Fall**, to hasten decomposition of dead foliage if the woods are in close canopy.
2. **A Seed Felling**, to stimulate production of seed by giving the tree-crowns more light and warmth.
3. **Gradual Clearance** of the remaining trees, to strengthen the young crop, as it requires more light, warmth, and moisture.

These different degrees of partial clearance of the mature crop are of course never carried out with anything like stencilled regularity. They vary greatly for each kind of tree, and for one and the same kind with changes of soil or situation. The whole method is really only suitable for trees not liable to be thrown by wind. To carry out all three kinds of falls with anything in the slightest degree approaching regularity is only possible with shade-enduring seedlings (Beech, Sycamore, Ash, Douglas Fir, Silver Fir). In Britain any preparatory fall would, in most cases, and especially on loamy soil, at once lead to rank growth of all sorts of weeds. For Oak or Scots Pine preparatory fellings may at times not be needed at all: there may perhaps be far less need to decompose a layer of dead leaves than to protect

Fig. 77.



Natural regeneration of Silver Fir in patches.

a. Young seedling growth, above which the mature trees have been cleared to provide sufficient light, warmth, dew, &c., for its healthy growth.
b. The fringe beyond *a*, now also being regenerated by seed shed from the trees on BB.
c. Exhibiting the method of extending the patches of spontaneous seedling growth.
BB. The total extent to which regeneration in the above group is being effected.

the soil against rank growth of weeds. But preparatory falls are usually necessary with the shade-enduring Beech and Silver Fir, which continue in fairly close canopy till mature, though they are hardly likely to be needed for Douglas Fir.

When a satisfactory seedling crop is on the ground, the old trees must be gradually cleared away so as to give the seedlings more light, warmth, and dewfall.

Light-demanding seedlings like Oak and Pine sooner become intolerant of over-shadowing than shade-enduring kinds: and on dry sandy soil any kind of seedling will need to be freed from shade at an earlier stage of its growth than on fresh or moist loamy soil. In the former case the seedlings droop unless they can obtain the benefit of the night-dews; while in the latter they can thrive with less light, and require protection against frost. When the old trees are cleared away good opportunity is given for introducing Oak, Ash, Larch, &c., in patches or as single plants.

The manner in which this method is applied to the chief kinds of trees grown in more or less pure woods in Germany is as follows (*British Forest Trees*, p. 74 *et seq.*) :—

Beech.—*Natural Regeneration* under parent trees forms the rule with this species, as the seedling growth demands, like the Silver Fir, protection against sun and frost during the first two or three years of its existence. The total area under wood is divided into four blocks representing respectively the area on which are to be found the portions of the growing-stock 0–30 years, 30–60 years, 60–90 years, and 90–120 years,—or averaging 15, 45, 75, and 105 years of age respectively, counting from the middle of the period of reproduction. Growing in closed canopy, the Beech here develops a long smooth stem well adapted for technical purposes. As already mentioned, three classes of fellings in the mature crop may be distinguished,—(1) *a preparatory felling*, (2) *a regenerative felling*, and (3) *gradual clearance* of the parent trees to strengthen the young growth. The first two fellings are made previous to regeneration, while the last is best carried out as gradually as local circumstances and the provisions of the working-plan permit.

The preparatory felling is made in order to stimulate the parent standards, through greater enjoyment of light and air, to speedy and increased production of seed, and at the same time to accustom them gradually to the isolation they must ultimately have before the final clearance, as well as to harden them against wind and scorching from sun-burn. The best opportunity is also at this time given to remove all the other species growing in admixture with the Beech, so as to confine the regenerative operations to the latter alone, subordinate species being best introduced later on. The soil-covering in mature forests in close canopy is seldom of such nature that it can at once offer a good germinating-bed for the seed; hence a certain deliberate interruption of canopy is necessary in order to allow rain, light, and warmth to accomplish the decomposition of the dead foliage covering the ground, except on the fresher and more fertile soil where the greater moisture has all along been more favourable to the formation of humus. Under ordinary circumstances, with a moderate preparatory felling, the decomposition of the soil-covering of dead foliage is accomplished in about four to five years. This takes place quickest on limy soil, where felling is sometimes hardly necessary at all, owing to the danger of the soil becoming overrun with weeds, but proceeds more slowly on the sandy varieties of soil.

In addition to the subordinate species, only the smaller dominated stems are removed, so that about 12 per cent of the cubic contents are harvested, which would include about every fifth to seventh tree of the smaller classes. The fall can always be greater on the cooler northern and eastern aspects, and in localities where the foliage lies thick: where the soil already shows tendency towards growth of grass or weeds it is unnecessary, and would be out of place. Young self-sown growth should only be allowed to remain if of good development and not over 6 to 8 years old, as Beech differs greatly from Silver Fir in respect to the recuperative power of seedlings that have stood long under dense shade, and such badly grown patches only interfere with a free circulation of the air, thus increasing danger from frost. By driving in cattle for grazing, or swine for pannage, the work of breaking up the soil and rendering it receptive for the seed is greatly furthered.

The seed-felling takes place when a good mast-year has come round, which can usually be foretold by the thicker swollen appearance of the future flowering-buds in autumn and winter, especially after a hot summer. About one-fourth to one-third of the crop then on the ground may be removed, those left as parent trees being preferably such as show a breast-height diameter of about 12 to 16 in., and have well-developed crowns which do not reach far down (Fig. 78). The largest fall of timber is permissible on soil not having a strong tendency to the growth of weeds, and is demanded by dry soil below the average in mineral strength, as in these latter localities the young seedlings derive most of their supplies of moisture from the nightly precipitations of dew, and though temporary shade does them no harm, the constant overshadowing of numerous standards cuts off their requisite supply of moisture in the form of dew and gentle showers of rain. The work of reproduction is greatly aided by driving in cattle and swine, and by the use of the rake in order to provide the beech-nuts with a covering of soil.[1]

The gradual clearance for strengthening the young growth and removing the remainder of the mature crop should begin in the year following the fall of the seed on dry soil, or where considerations in regard to it have made a comparatively dense overshadowing of the parent standards desirable during the seed-year. But under ordinary circumstances they are not begun until the seedling-growth is two years old. The rate at which the gradual final clearance takes place depends to a great extent on the vigour of the seedling crop, for where this shows that fuller exposure to light, air, and atmospheric precipitations are required, the standards should be first removed. As it is during the final stages of the gradual clearance that the greatest increment in girth takes place on the standards, they are retained wherever, and so long as, they do not appreciably injure the young crop. The second fall usually takes place about two or three years after the first, and the others after similar periods, but these can be hastened where danger from frost or weeds is not to be apprehended, or where the soil is deficient in moisture. On the average, the final clearance is effected in about ten to twelve years from the mast-year. On warm dry exposures it has often to be carried out within six to eight years ; whilst on cool aspects with moist soil it may be extended over fifteen to twenty years, during which period it should be conducted very gradually (*op. cit.*, pp. 181-184).

Oak—*Natural Regeneration* can be accomplished in mature pure forests of Oak, or where it is the ruling species in mixed forests, as in many parts of Northern Germany, France, and Austria, simply by the removal of the subordinate species, or by a seed-felling made during the mast-year and confined to the small-girthed Oaks, so that on the average about fifty to sixty trees will be left per acre (Fig. 79). But as old Oak forests, and mixed forests with Oak as principal species, have usually only a patchy growth of mature trees to show, the disposition of the parent standards over the area is seldom so regular as in the case of the Beech. The probability of a seed-year can be foretold, although not so plainly as in the case of the Beech, by the larger swollen appearance of the future flowering-buds during autumn and winter, signs chiefly to be met with after warm summers favouring the formation of starchy reserves.

Whenever the soil is suitable for the reception of the acorns, a good flush of seedling growth follows the mast-year, but, in order to take full advantage of it, herds of swine should, if convenient, be driven into the woods for pannage, as, though they feed on the acorns, they do much more good than harm by treading the seed into the ground, and by disturbing the soil-covering both with their feet and with their snouts. Where such simple means are not at hand, some artificial assistance must be given by dibbling or treading in the seed, or by hoeing the ground, as unless the acorns have a covering of earth about 1 to 1½ in. deep, they are apt to lose their germinative power through the frosts of the ensuing winter.

Even in mixed forests of Beech and Oak, a good acorn year is generally followed by a fair growth of seedlings of the latter species, which only require light and air, through clearance of the standard trees, to enable them to develop normally into groups of Oak. But whenever, under the light shade of aged Oak trees, the soil has any strong tendency to growth of grass, natural regeneration is less likely to yield satisfactory results than planting, and in general it may be said that regeneration under parent standards offers its best results on soil of only average or inferior quality: more or less of artificial aid is, however, usually requisite under nearly all ordinary circumstances.

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[1] Soil-preparation is also, of course, of great assistance in forming the new seedling crop. Such preparation can best be carried out in strips about 20 inches broad and from about 3½ to 5 ft. apart, which means hacking up and preparing from about ¼ to ⅓ of the actual acreage of the seed-felling area. If these strips are not sufficiently stocked by the fall of the seed, they are sown with beech-nuts.

Fig. 78.

Seed-felling (in foreground) and Gradual Clearance (in background) during Natural Regeneration of a mature Beech-wood (Lyons-la-Forêt, Canton de Pain d'Epices).

Fig. 79.

Seed-felling in an Oak Highwood (Forêt de Bercé, Sarthe).

In order to utilise a good seed-year to its fullest, the area over which the seed-felling extends should comprise the fall of several successive years; but care must be taken not to include more annual falls than can be totally cleared during the period of regeneration, as the seedling growth demands the speedy removal of the parent standards. It is better to await the advent of the next good seed-year for a portion of the area than to comprise too many annual falls in any one seed-felling. Wherever convenient, the largest standards, whose felling and dressing would be most likely to do some injury to the seedling growth, should be removed at once after the fall of the mast, and during the subsequent clearances of the mature crop it is well to remove the largest stems first.

When Oak-woods are being regenerated naturally, the admixture of Beech on drier situations, and of Ash, Elm, Maple, Sycamore, or, where advisable for soil-protection, Hornbeam on those that are moister, can easily be accomplished by sowing seed. If these species are only introduced by means of planting when once the Oak is in active growth, they run great risk of being suppressed (*op. cit.*, pp. 206-208).

In the Spessart, in Bavaria, the sowing of acorns is often done on what is called the "ladder-system," the acorns being sown in rows (like the rungs of a ladder) from 8 to 10 in. apart, with about 2 ft. between the lines.

Scots Pine.—No protective standards are necessary for natural regeneration, because on poor soil the seedlings cannot endure shade, and on good soil they can thrive without shelter, and soon need the removal of the parent trees. Natural regeneration under parent standards can therefore only be recommended on good soil and situation, where the increment on the parent trees more than compensates for the loss through overshadowing the young crop. Where self-sown seedlings are to be found with good leading-shoots, the timber should be removed sooner than in other parts, so as to let the young seedlings grow up in groups or patches; for if once dwarfed and stunted through overshadowing, such seedlings never completely recover. Thus a young self-sown crop, which has stood for more than two or three years under the shade of close canopy, or older plants under more open cover which show a shortened and impaired growth of the leading-shoot, do not yield suitable material for the formation of future crops, in addition to which the extraction of the parent trees can seldom be effected without causing a good deal of damage to the young undergrowth. The retention of self-sown seedlings occurring only singly here and there on areas that are intended to be stocked with pure forest of Pine is not advisable, as they are apt to break into undue branch development, do not form good boles, and generally interfere with the growth of their neighbours.

In mixed forests where the Pine is grown along with thickly foliaged trees, or in Pine forests that have been underplanted with shade-enduring species, some soil-preparation is necessary for the purpose of accelerating the decomposition of dead leaves and the formation of humus. In pure forests of Scots Pine, however, it is more often the case that reproduction is hindered by a heavy growth of grass and weeds, amongst which germination of the seed is difficult and the malformation of the seedling almost certain; for good development of the young plant can only be expected where the seed rests on the naked soil, and the rootlets can penetrate immediately into the earth. Even where the ground is only covered with weeds here and there, some soil-preparation is needed; otherwise the young crop is patchy and at best unequal in height—conditions not at all suitable for the formation of pure forests of a light-demanding species like Scots Pine, which only forms good stems when the density of the crop is sufficient to stimulate growth in height by interfering with and checking the natural strongly marked tendency to ramification and coronal development. Such soil-preparation need not take place over the whole area, but is at least advisable in bands or strips of 12 to 20 in. broad, occurring at intervals of 3 to 4 ft. The covering of weeds should be removed till the soil is reached, and this should if possible be slightly broken up early in spring, so that the seed may find a good bed for germination on being shed from the cones with the advent of somewhat warmer weather.

Where the quality of the soil is good enough to make natural reproduction advisable, twelve to twenty parent standards per acre, equally distributed over the area, will be found sufficient, especially if high-forest of the same species be near the fall and assist in the distribution of seed. Where, however, it is desirable that the advantages of increased growth in girth, through freer exposure to light and air, should be attained by a greater number of stems before they are felled and extracted, this can be arranged for by reproducing in circles of 40 to 50 yards diameter with very few standards surrounded by a belt or girdle of 10 to 20 yards broad in which the seed-shedding parent trees are more numerous. The standards are first removed in three to four years from the central area, and those from the girdle gradually during the next ten to twelve years. If under the latter the germination and establishment of the Scots Pine has not been successful, other species can be sown, and thus at the end of the period of reproduction the area will be covered with circular groups, of about one-third of an acre each, consisting of Pine of equal age, surrounded by belts, 10 to 20 yards broad, of shade-enduring trees like Spruce or Silver Fir, in which patches of Pine also occur, whereby to a certain extent the advantages of mixed forests will be attained.

On the poorer classes of soil natural reproduction is not advisable, although where groups or large patches of well-developed self-sown seedlings have asserted themselves on blanks occasioned by windfall, &c., their retention is often advisable. Where a recent fall of timber has taken place, a natural growth can often be obtained if strips be prepared for the reception of seed whenever numerous cones on the neighbouring trees to the windward side show prospect of a large supply of seed being shed in the following spring in the direction of the area to be re-wooded. But such natural reproduction cannot be relied on for more than 100 to 120 yards, and is often extremely irregular and unsatisfactory, necessitating considerable outlay for the filling up of blanks. As germination can only be secured on dry soil when the seed has some soil-covering, it is advisable either to break up the soil before the time of seed-shedding, or to go over it lightly with the rake or harrow after the seed has fallen. A favourable germinating-bed is afforded by places where the stumps of the trees have been grubbed out to decrease the number of breeding-places available for injurious insects.

In the Pine forests of Northern Germany natural regeneration over large areas has long been given up, and total clearance of the mature crop is at once followed by sowing or planting operations, except near the edge of next year's fall, where, for the distance of about 100 to 200 yards, there is sometimes a growth of self-sown seedlings from the seed shed during the last year, which is often capable of forming close canopy with more or less of artificial assistance (*op. cit.*, pp. 74-77).

In some of the Southern German Pine woods narrow clear falls are made not exceeding in breadth the height of the trees, and these seed themselves naturally by the seed blown on from the windward (the falls being made against wind).

Larch is seldom regenerated naturally, planting being preferred, because, like other deciduous trees, transplants can be put out at almost any age.

Where practised at all, natural regeneration only takes place along small strips at the edge of mature woods whence the seed might be wafted. Many of the mixed forests in Switzerland and the Bavarian Alps are thus formed, the seed germinating readily when falling on broken ground.

Spruce.—When reproduced naturally under parent standards, no preparatory fellings are necessary to stimulate seed-production and prepare the soil for its reception. When a good seed-year seems favourable for regenerative fellings, they are made so as rather to resemble those in Beech and Silver Fir than in Scots Pine forests; but on account of the danger from wind the number of trees left per acre is greater, only from one-fourth to one-third of the total number of trees forming close canopy being removed, so that during storms the crowns can afford each other some measure of support. On moist soil a sparser number of parent trees would also favour rank growth of weeds, which is more prejudicial to young Spruce than even a considerable degree of shade from lofty standards. The period of regeneration is much shorter than with Beech or Silver Fir, as seed-years are more frequent, and the amount of seed produced greater, besides which the young seedling growth is not so absolutely shade-demanding as with these other species. From the Pine it also differs essentially, not only in the more abundant, though not more frequent, production of seed, but also in that the seed ripens in about six months, in place of being delayed till eighteen months after the flowering.

The shape that it is advisable to give the area to be reproduced is dependent on the extent of the danger from wind: the greater the danger, the more should regeneration take place in long narrow strips, on which the number of trees along the middle should be greater than towards the edges, so as to ensure speedier regeneration and earlier clearance of the parent trees, in order to minimise the damage caused to the seedling growth at the time of extraction. Where good patches of self-sown Spruce occur, they should be retained, but all other species of trees should be cut out. When practicable, large branches should be sawn off to decrease the leverage obtainable by the wind; but care should be taken to carry out this operation during winter, in order to prevent the outflow of sap from the wounds. Whatever soil-preparation can be conveniently undertaken yields its reward in easier and better growth of seedlings; the layer of thick moss should at any rate be removed with the rake. In Prussia, breaking up the soil roughly into clods in bands or strips 1 to 1½ ft. broad and 6 ft. apart has been found advantageous, the operation being performed in the autumn of the seed-year.

The clearance of the standard parent trees commences in the winter of the year following the seed-shedding, and the extraction should take place, so far as possible, whilst snow lies on the ground, in order to minimise the injury done to the seedling crop. Clearance must be effected as speedily as possible, as the danger from wind increases greatly when once this operation has been begun: even in sheltered localities the final clearance should be completed by the time the seedlings have attained a height of 1 ft. Where reproduction has not been equally and uniformly successful, it is not advisable to retain the standards; blanks can easily be filled up by sowing or planting, or an excellent opportunity is thus given for introducing other species, such as Silver Fir, Beech, Pine, or Larch, whose admixture along with Spruce has been shown by experience to be very desirable (*op. cit.*, pp. 106-109).

Silver Fir.—Before any special clearing is made for regeneration, a heavy thinning is given to stimulate the production of seed. When the actual felling for regeneration takes place about ten years later, the extent of this preparatory fall mainly depends on the nature of the soil, the greatest number of trees being retained on fresh or moist patches where the young crop is likely to suffer less from overshadowing. On drier patches regeneration in groups is preferable, where the seedlings can have the full benefit of rainfall and dew whilst still obtaining the protection of side-shade; in hollows, and coombs, and all other places where frost is to be feared, the disposition of standards should be nearly equal over the area. This clearing for regeneration should be made when the number of cones shows a favourable year, as otherwise, should the seed-harvest fail, moist soil is apt to become overgrown with weeds, and dry soil to become somewhat deteriorated. Where self-sown growth has already taken possession of the soil in patches, it should be tended as far as possible by removal of standards above it, especially of those in the centre which are likely to do most damage by overshadowing. By this method of regeneration, however, considerations regarding the young crop are really subordinated to those relative to the greater profit to be expected in the harvesting of the mature crop, so that in general the canopy of the standards is interrupted only so far as to ensure the ultimate wellbeing of the younger growth, when it at length attains the enjoyment of a greater measure of light and air. The clearance in a seed-year is therefore, under normal conditions of soil, usually confined to such interruption of the canopy that the crowns of the standards cannot close up again for the next four or five years. Atmospheric precipitations can, under these circumstances, reach the soil in sufficient quantities to satisfy the young crop, whilst, should any accidents befall the seed or the young seedlings, the canopy above is sufficient to protect the soil against rank growth of weeds on moist soil, or deterioration on dry, until another good seed-year comes round. As a matter of course, the first trees to be removed are those of subordinate species, and also such as are not likely to profit much from further retention.

Wherever the soil seems to have good receptive capacity for the seed, which is particularly the case when the soil-covering consists of a thin layer of *Hypnum* moss, an average interruption of the canopy may be made without any hesitation; and where such thin layer of moss, or a slight covering of dead leaves, or perhaps a very light growth of grass, is found on the soil, no preparation is usually necessary to stimulate it for the reception of the seed. In places where there is a tendency to a strong growth of grass on moist soil, it usually happens that the previous measure of light accorded has already, without any seed-felling, resulted in a self-sown growth of young Silver Fir, before the light became strong enough to favour the ranker development of the weeds. But, as might be expected, the more difficult problems of natural regeneration of this species have to be faced where the soil is deficient in moisture, or where there is a strong tendency towards rank growth of grass. Where the layer of moss is thick, or the covering of whortleberry or heather is at all considerable, some measure of soil-preparation is seldom avoidable. In the former case the removal of the moss with wooden rakes in strips of 12 to 16 in. will be sufficient, but in the latter some work with the hoe may be necessary, the strips being usually made about 18 to 24 in. broad, and in either case, of course, prepared before the fall of the seed during autumn. Under ordinary circumstances the seed requires no artificial covering, but in localities where seed-production is somewhat deficient, and where there is probability of early germination and consequent danger from late frosts, it is advisable to go over the strips with iron rakes after the seed has fallen, unless the soil has been previously broken into clods with the hoe.

Where woods are wanted in which the annual or periodic fall is to consist of timber of about equal age, there is less necessity than in the case of the Spruce for dividing the total area under Silver Fir into separate independent blocks, each having its own growing-stock of all ages from one year, or the mean age of the first period, up to maturity, or the mean age of the last period. The rate at which the clearance of the standard trees takes place after natural regeneration has been satisfactorily carried out, depends to a great extent on local circumstances (Fig. 80): in some places it is gradually performed by the annual removal of a portion, in other places a heavier fall takes place only every four or five years. Most anxiety is caused on moist soil where there is no proper covering of moss, but a strong growth of grass instead, or again on dry slopes with southern exposure. On good fresh soil the retention of the standards in greater numbers does not permanently injure the seedling crop, but on dry situations deficient in soil-moisture a speedier clearance must take place in order to let the young growth have the full benefit of dewfall, without which any considerable degree of overshadowing might soon permanently damage the weakly crop, or materially prejudice its ultimate recuperative power after removal of the standards. On dry soil the total clearance can hardly be delayed more than eight to ten years after the seed-felling, and in some cases it is advisable to complete it as early as the fifth or sixth year.

In addition to considerations as to the direction of prevailing high winds, some heed must be taken in regard to the extraction of the mature timber from the regenerated areas in such a manner as to entail least injury to the young crop. This is best effected when the regenerative falls are begun from above, instead of from below, as would be the case if only danger from storms required to be taken into account. In addition, the areas on hillsides are not felled over in oblong but in rhomboidal form, and at as sharp an angle as convenient, in order that on the extraction of mature trees the timber may be dragged as speedily as possible into the tree-forests adjoining, and which will be the next to be operated upon. That, of course, such areas should be as long and narrow as possible hardly requires mention; but local circumstances of soil and situation assert themselves just as much in this as in most other matters. Greatest damage is done to the young growth when the felling and the extraction of the mature stems take place in winter during frost and without a heavy fall of snow on the ground; less damage is done when operations take place in summer, especially after the young shoots have hardened fairly, and when the stems have been barked to avoid attacks of weevils and bark-beetles, and to make it lighter for transport and whiter in appearance (*op. cit.*, pp. 131-134).

Natural Regeneration of Oak in Britain was originally solely by means of **Encoppicement** or **Enclosure**, with prohibition of grazing, and this simple method still gives good results in both Oak and Beech woods in the Forest of Dean. There, as elsewhere, acorns are specially plentiful every 3 or 4 years.

The practice of cultivation seems to have been that of "natural regeneration," such as is advocated by the most distinguished foresters of the modern school. In old days it went by the name of **encoppicing**, and the process seems to have been simply to enclose the area by a fence against cattle and deer, and to rely on the natural reproduction of the

Fig. 80.

Natural Regeneration of Silver Fir
(Forêt des Elieux, Meurthe-et-Moselle).

Fig. 81.

Natural Regeneration of Scots Pine (Beaufort, Inverness-shire, 1899).

seed from the existing crop of trees to replenish the wood. After the coppice was fairly established, it seems to have been the practice to farm it out on lease for a term of years, but under certain restrictions as to the preservation of timber. Thus in A.D. 1571 we find a presentment of the regarders of the forest to the effect that "a coppice called Ridley Coppice hath been spoiled by cattle by one John Marlowe." To this careful attention, it may be, we owe it that we are now able to enjoy the beauties of Ridley Wood—without exception the most beautiful of all the woods of the New Forest as it now exists. Such presentments, however, abound in the records of this reign, and it is clear that great pains were taken to keep the numerous young coppices free from all manner of cattle. These coppices are the old woods which are the glory of the Forest at the present day (Lascelles, pamphlet on *Arboriculture in the New Forest*, 1893).

The above is, however, a somewhat haphazard method, because if softwoods are in the vicinity Birch, Willow, and Aspen may spring up in large numbers. It is therefore better to prepare the soil when a good seed-year is in prospect, regenerate as quickly as convenient, and fill up blanks in the young crop by planting. The acorns often, however, seem to germinate best on a grassy surface, but of course they damp off and die unless the rootlet can reach the mineral soil. Where wood-pigeons and pheasants are numerous, natural regeneration is only likely to be partially successful, as they feed eagerly on the acorns; and of course mice and squirrels are specially destructive.

Natural Regeneration of Scots Pine (Fig. 81) is usually easy unless there be a strong growth of weeds, and the mature trees have generally to be quickly removed to give the seedlings sufficient light and moisture. Where there is heather on the ground, the seedlings germinate much more freely and come up in larger numbers and far more regularly than where the soil-covering consists only of bracken, grass, and other herbage. The falls for regeneration are usually in Scotland made at intervals of 2 to 3 years, either by clearing in strips of 200 to 300 yards in breadth (beginning at the windward side and working up against the wind), or by cutting in patches, or by leaving only about 20 to 30 seed-bearing trees standing per acre. Owing to infection from dead foliage, enormous numbers of germinating seedlings are probably killed by the fungi *Botrytis cinerea* and *Lophodermium* (*Hysterium*) *pinastri*; and this no doubt explains the fact that Scots Pine seedlings usually spring up far more numerously in the open, or under the light shade of broad-leaved trees and Larch, than under the direct shelter of the parent seed-bearing trees, where the soil is covered with the dead pine foliage undergoing humification, and therefore infected with saprophytic fungi capable of becoming parasitic on the seedlings.

Wherever there is too strong a growth of heather, regeneration can be greatly assisted by grazing sheep on the area to reduce the growth of weeds, and to break up and prepare the soil for the seed. But as soon as the seed is ready to fall, the tract must be closed to grazing and protected against cattle, sheep, and deer.

It is easy in Scotland to perpetuate a forest by natural means, and of this a practical proof was given us in two forests which we visited—the one near Grantown, in Strathspey, the other at Beauly. In these the results obtained, under the skilful and intelligent direction of the gentlemen who manage these forests for their employers, form a striking example of what may be done in the way of reproducing forests by natural means.

In fact, nothing had been neglected which even the most critical forester could desire: the gradation of age was here complete, and the reservation of specially vigorous trees of known pedigree duly carried out. The *modus operandi* here pursued consists simply in the exclusion of the sheep and deer, in the judicious thinning out of the growing crop, and in the removal of the mature seed-bearing trees by successive fellings as the young forest grows up and acquires more vigour (Boppe, *Forestry Committee Report*, 1887, Appendix).

Natural Regeneration of Beech on the Chiltern Hills (Fig. 82) is generally carried out by means of gradual clearances extending over from about 10 to 30 years. During this period regeneration is usually left entirely to chance, as seed-years recur every 5 to 7 years, and the soil is generally favourable to the growth of seedlings. But there can be no doubt that the Continental methods of assisting nature by herding cattle and swine in the woods, and by preparing strips of about 18 to 20 in. broad at distances of from 3½ to 5 ft. apart, would lead to better results and prove a profitable means of establishing a good thick crop of seedlings.

The year 1900 was a splendid seed-year on the Chiltern Hills. That such was likely to be the case was clearly apparent from the large proportion and size of the flowering-buds during the winter 1899-1900; but, notwithstanding this fact, little or no soil-preparation seems to have been then generally made in mature woods for the reception of the seed in the autumn of 1900.

Natural Regeneration of Ash, Maple, and Sycamore is easy, as they produce seed abundantly every year or two, and all the attention that the seedlings need for the first few years is protection against rabbits.

The Elm reproduces itself freely on suitable soil by throwing up suckers, which also require protection against ground game.

Fig. 82.

An English Beech-wood, mature and awaiting Natural Regeneration (*Tring Park, Herts*, 1900).

CHAPTER VII.

CONCERNING ARBORICULTURE,

OR PLANTING FOR ORNAMENT AND SHELTER.

Arboriculture in Home Parks.—Landscape-gardening is not the forester's work, and all that he may usually have to do with it is to plant trees when and where ordered. But it is well that he should study the main principles in question, so as to give sound advice if asked for his opinion.

Each kind of tree has its own characteristic *outline* that will stand out against the background, consisting of other trees or grass-covered slopes, or of the open sky; it has its distinctive *colour* of bark and foliage in spring, summer, and autumn, and its specific *form* of branches and twigs that will become plainly apparent during the long leafless months of winter, unless the trees be evergreen. The desirable amount of harmony and variety can only be attained by carefully considering beforehand the effects obtainable by single trees, small clumps, and larger pure or mixed groups at each of the different seasons of the year,—due consideration being given to the actual conditions of soil, situation, and environment. Artistic and æsthetically satisfactory results can seldom be achieved by casual planting, without plan or method—though here also, of course, *ars est celare artem*.

The position and surroundings of the residence must first be considered. The easiest situation to deal with is a gentle southern slope, with rising ground behind to form a background of woods. The park should not be formal in outline, but irregular, and, if possible, of much greater length than breadth, so as to give an extensive view towards the front of the house. An undulating surface is favourable, as a flat stretch is naturally rather monotonous; and no landscape can be considered complete without water, in the shape of either a running stream or a lake. Knolls and other rising ground behind the house should be planted with trees suitable to the soil and the climate. The dark canopy of Conifers forms a better background than broad-leaved trees in winter, while in summer they contrast well with the lighter green foliage of deciduous trees. Behind the house, the plantations on rising ground should extend as far back as space allows, so as to convey the idea of a continuous wood beyond that, and give an extensive aspect to the domain. They should extend so as to flank the house on the east and west sides, and should come down from the high ground with a bold sweep on each side. Shelter will thus be given against winds from the north, east, and west, while the view from the house is left open towards all the southern aspects.

Plantations should be made all along the park boundary for shelter and to hide undesirable objects, and to bring more prominently into notice any desirable features, such as a lake or a stretch of river. These plantations should be made with bold curves following the natural undulations of the land, while glades should be left here and there, giving glimpses of the country beyond. The park itself should be adorned with groups of trees of different kinds, if not already provided with fine old Oak or Elms. And in planting groups care should be taken to place the young trees so that they do not form any regular geometrical figure, like an equilateral triangle, square, octagon, &c. Such formality is certain to offend the eye from some point of view, and it can never be obliterated later on. Even the oldest Oaks in Richmond Park suffer from this irremediable defect, due to the plantations having originally been made in lines for growing Navy timber. Hard straight lines should always be avoided, both in laying out plantations and in planting the trees, because a graceful curve is always more pleasing to the eye in rural scenery, although time helps to soften the straight edge of a wood when the crowns of the outer trees expand. Trees planted here and there outside the fence relieve the hardness of line.

The land near the house should be left open to form a lawn, with only a few trees on it, and the groups of park trees should be made more massive with increasing distance from the house, though not so large as to look like the close canopy of a wood. The main drive should, if possible, enter the park at some point where there are old picturesque trees, and where an open glade gives a distant view. It should then be carried forward in a bold sweep, giving the best view of the park and the distant scenery. The house should be kept out of sight for the first half of the drive; and the approach should give a glimpse of the garden before coming to the main entrance, from which a view of the whole park should be obtainable.

As regards the kinds of trees most suitable for ornamental estate and park planting, much of course depends on the given soil and climate; but in favourable localities, among broad-leaved trees, Oak, Elm, Beech, Spanish Chestnut, Horse-Chestnuts, Maple, and Lime produce on the whole the most pleasing effects; while among evergreen Conifers, Spruces, Douglas Fir, and Silver Firs are generally the most effective, with Willows and Poplars near water, and Deodar, Cedar of Lebanon, Cryptomerias, Cypresses, and similar hardy exotics in closer vicinity of the house. Sycamore has too hard and formal an outline to look well as a park tree, and some of the introduced Conifers (such as *Araucaria* and *Sequoia*) are certainly more quaint than beautiful. Groups of Scots Pine have, especially when old, a fine effect on the top of a hill against the sky-line, while a sprinkling of Ash, Rowan, and Larch in the front part of woods produces a good effect in spring. On slopes, single shrubs and groups of Hawthorns are much to be recommended.

To screen undesirable objects from view, quick-growing evergreen trees like Douglas Fir, Menzies Spruce, Lawson's Cypress, Banks' Pine, the Lofty Pine, and Austrian and Corsican Pines are most to be recommended, while among deciduous trees the Sycamore, Sweet Chestnut, the Tree of the Gods (*Ailanthus*), False Acacia (*Robinia*), Plane-tree, White and Red Willows, and White Poplar, all offer special advantages under particular circumstances. For poor sandy soil, the choice of species is far more restricted, and Banks' Pine is one of the trees most likely to grow quickest and form an evergreen screen.

Although these trees all grow rapidly under favourable circumstances, they are likely to do best if the soil be well trenched and aerated before planting. But unless the trees are suitable for the given soil and situation, they are not likely to prove satisfactory in the long-run.

For **ornamental underwood** the following (partly deciduous, partly evergreen) may be recommended :—

On dry loam—Dogwood, Box, Hazel, Laurel-bay, Aucuba, Cotoneaster, Philadelphus, Spindlewood, Snowberry, Spiræa, Hemlock-spruce, Broom.

On sandy loam—Yew, Elder, Butcher's broom, American Arborvitæ.

On light sand—Juniper and Sea-buckthorn ; Tamarisk near rides.

On rich fresh loam—Holly, Laurel, Privet, Blackthorn, Guelder-rose, Barberry, Laurustinus, Rhododendron, Hornbeam, Spruce, Silver Fir.

On peaty soil—Rhododendron.

On rocky parts—Ivy, Juniper, Elder, Hazel, Yew, and Dwarf Pines.

Where underwood is wanted either for game-cover[1] or for ornament, well-disposed groups of Laurel-bay, Holly, Portugal Laurel, Hemlock-spruce, and Privet may be planted in patches of about $\frac{1}{16}$ to $\frac{1}{8}$ of an acre, wherever the broken canopy of the standards favours their formation; while it is best to keep the low-growing and ornamental flowering Rhododendrons, Cotoneasters, Philadelphus, Snowberry, Spiræa, Mahonia, Roses, Laurustinus, and Aucubas next to the rides and drives, where their full effect can be enjoyed. In winter especially, the evergreens are effective in contrast with leafless broad-leaved trees. Such slight points are often by far too little attended to, and the winter scenery of our woodlands might often be greatly improved at a comparatively trifling outlay.

Laying out Plantations for Shelter and Ornament.—So far as convenient, no plantation formed for shelter on an exposed situation should anywhere be less than 100 yards broad, and even a breadth of 100 yards may be too little where the soil is light and shallow. On mossy ground or poor thin gravel, a narrow or small plantation will not thrive, although it may succeed on good loam in a sheltered situation.

Almost every estate has some peculiarity, and the local climate, especially the winds, should always be considered in laying out plantations.

The Whitelands estate, for example (see Fig. 83), situated on the west side of a hill *a*, running nearly north and south, is sheltered from storms from the E. and S.E. ; and in laying out plantations, their broad side should run from E. to W. to protect the land from N. and S. winds ; and other plantations would have to run from N. to S. (farther westwards than the hill) to protect land from violent W. winds.

The Newbury estate, however, situated on the E. side of the hill, is sheltered from W. and S.W. winds, but exposed to N. and E., so that shelter-belts running with their long side E. and W. will also protect land from N. or S. winds, while plantations with broad side running N. and S. will protect it from the cutting E. wind.

As there is a pass or gorge between the S. end of the hill *a* and the N. end of hill *b*, —the N. lands of Ashwell being on the W. side, and those of Bucklands on the E.,—care is necessary in laying down plantations there ; because in passing through such a gorge,

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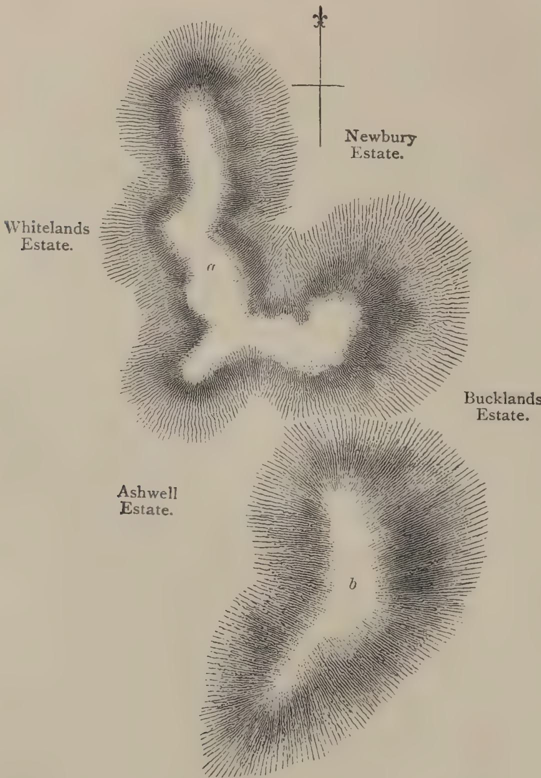
[1] See also H. Upcher's chapter on *Planting Coverts for Game*, in vol. ii. of *Shooting* ('Country Life' Library of Sport), 1903.

the wind gathers force from being confined in its passage between the hills.[1] The best sort of shelter to form here is a mass of plantation having convex sides to E. and W. so as to try and turn the wind to either side.

To protect land on the W. of Ashwell from N. and S. winds, plantations would have to run with their broad side from E. to W.; and to protect them from W. winds, the belts must run from N. to S.

Fig. 83.



Upon Bucklands estate plantations laid out from E. to W. will protect from N. and S. winds, and those running N. and S. will screen off the E. wind.

As the success and the ornamental value of young plantations depend greatly upon the way they are laid out, the following general rules may be of use :—

1. In laying out the boundary, avoid, if possible, any straight lines, and make none on the exposed sides. Straight lines always offend the eye, and they are most exposed to violence of storms.

2. The long side of a plantation should extend at right angles to the direction of the prevailing wind of the district, and should be kept along the highest part of the land to be planted (if possible).

3. A convex boundary on the most exposed side of a plantation affords the best protection against wind; for the violence of the storm decreases as the current of air is able to spread out sidewards.

4. On sheltered sides the boundary may incline one way or another to obtain the effect desired. But a concave bend should only be made with a good depth of plantation immediately behind it.

5. If not too elevated and exposed, the highest land should be chosen for planting. This gives the maximum of shelter attainable for adjacent fields, and at the same time a plantation on a height always forms a prominent and pleasing object.

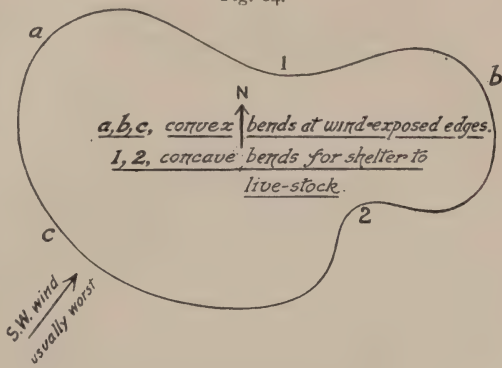
6. In laying out plantations for shelter of live-stock on a high exposed country-side, there ought to be deep inward bends on the sheltered sides. These indentations

[1] It was just to the E. of such a gorge, near Comrie in Perthshire, that the memorable storm of 17th November 1893 occurred. The wind, following continuous and heavy rainfall, came sweeping through from Loch Earn and gathered fearful violence when pressed in between the hillsides, so that extensive woods to the E. were thrown entirely. The damage done by that storm in Perthshire and Forfarshire alone was estimated at 1,500,000 trees, valued at £300,000. It swamped the market for timber in that locality, and it was years before all the windfall trees could be disposed of.

should be bold, large, and well rounded-off, otherwise the corners at such places will always look wind-swept and mean.

7. If it should be necessary to make a concave bend facing the side from which the worst wind usually comes, then care should be taken to make the bend in a low hollow part of the ground, and it should be backed by a good breadth of planting behind.

Fig. 84.



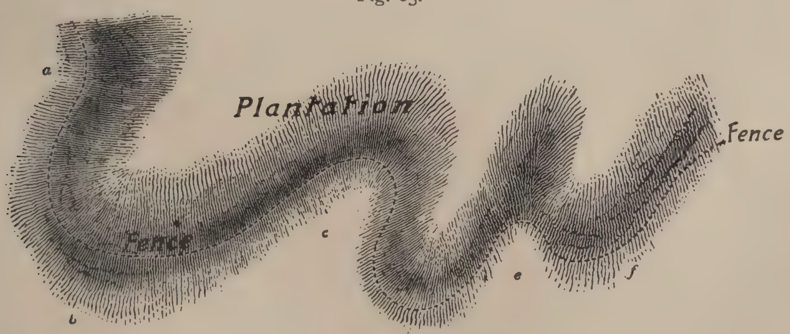
In Fig. 84 is given the outline of a plantation having its exposed sides *a* and *b* facing the N.W. and N.E., and offering two convex lines to storms from these points.

The outer trees forming the bend and those growing behind them are, from the very position they occupy, better able to resist the storm than those forming a straight line or a concave bend. When the storm-wind impinges upon the convex bends at *a* and *b*, its force is not exerted against this obstacle to its onward course, but the current of air becomes easily deflected along the convex edge of the plantation.

The concave bend 2 is backed by a great breadth of planting to the north, and is also well protected by the convex bends (*b*) on N.E. and (*c*) on S., while its situation is on the sheltered side, the S.E. The fewer of such concave bends there are the better for the growth of the plantation, but it is often necessary to make them for shelter to live-stock. If there were no concave bend at 2, cattle could have no shelter there from an E. wind; but in such a case as here shown stock would not be exposed to any wind except the generally mild S. wind.

Bends in the outline of a plantation should always follow the natural rise and fall of the ground. Where lateral heights project from the main part of the land, the line

Fig. 85.



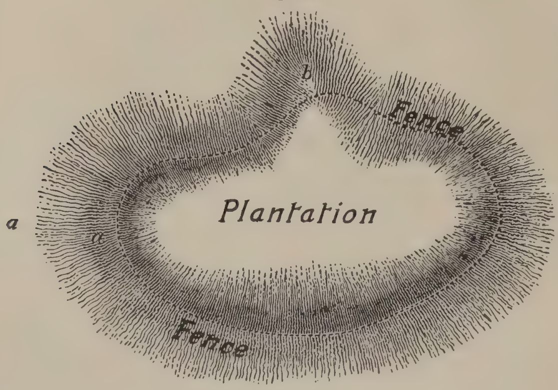
should make a bold convex sweep in the same direction as far as necessary; and wherever there is a hollow, the line should take a deep concave turn, coming up again in convex form where the ground begins to rise.

This may perhaps be more easily understood by Figs. 85 and 86. Fig. 85 represents a hillside laid off for an ornamental or shelter-wood plantation, the dotted line showing the fence. The concave bend (*a*) is in a sheltered hollow; and the convex bend (*b*) rises over the adjoining high ground, but is not extended to the extreme bottom of the hill, because it is often good to retain some of such high ground in the field, so that stock may have the benefit of lying there when the lower ground may be very wet. The concave bend (*c*) extends far into the hollow, for such a sheltered coomb is always very beneficial to farm live-stock at all seasons of the year, affording protection against wind in winter and giving shade in summer.

The convex bend *d* is extended beyond the bottom of the hill to give good shelter to the adjoining hollow (*c*); while similarly the concave bend at (*e*) is also sheltered by the convex bends *d* and *f*.

Fig. 86 represents an exposed hill to be planted. At *a* the hill runs out to a point, and the line of fence is kept higher to give a good, wide, convex bend. Had the fence at *a* just been brought out to the tail of the hill, it would have formed a long narrow point, which should be avoided. Similar remarks apply to *b*, where the fence is also kept back to improve the appearance.

Fig. 86.



If the new plantation is visible from the mansion or the pleasure-grounds, care should be taken to ensure its having a pleasing effect. Grace in the outline should be considered, and mixed woods should be formed in preference to pure woods of any one kind of tree. Deciduous trees should be scattered throughout evergreen Conifers, and *vice versâ*, so that pleasing contrasts may be obtained in spring and autumn, and that the woods may never be altogether bare and leafless in winter. Rides and drives throughout the woods should also be edged with trees of different kinds from those forming the plantations, so that the eye may always be charmed with a certain amount of variety in the colour of leaves and bark, and in the form of the stem, branches, and crowns of foliage.

In addition to hillsides, the planting of ravines and other hollows, frequently of very little agricultural value unless in the form of broad coombes, may often be profitable for growing timber, because even on inferior soil trees often thrive better on slopes and in hollows than on level land.

In laying out hollows or ravines for planting, the boundary-line should correspond, so far as possible, with the natural line of the slope. In glens or hollows there is often a cold wind not felt on the higher ground; and such cold winds are injurious to crops in the adjoining fields, particularly when there are late frosts or cold damp nights in spring. The bad effects of these can be prevented by planting so that convex bends rise out of the hollow and extend some way upon the level ground above, endeavours being made to bring up such a bend at a part most likely to intercept the cold current of air and to extend to some distance. The effect is best when some trees come over the fence.

Shelter-belts or Wind-screens.—Shelter-belts in the form of strips have a poor and mean appearance throughout a large estate; but, wherever they are found, they are of great advantage in all the wind-swept parts of Scotland and Ireland. Unfortunately, there are as yet far too few of them. As economy is usually necessary, and the main object is to offer as much resistance as possible to the onward progress of the wind, they are generally made in straight lines, and from 20 to 40 yards broad. In such narrow belts of wood the trees are, of course, very seldom found thriving, as is hardly to be wondered at. The strips being so narrow, the trees themselves are never sheltered to anything like the same degree as is the case in extensive woods, and consequently the timber is never so good. What may be the best kinds of trees to plant for forming such wind-screens depends on the given soil and situation. But whatever trees be planted, it is always best to plant them in double squares (quincunx) or equilateral triangles, so as to give each tree the best opportunity for forming a good crown of foliage (see also remarks on p. 409).

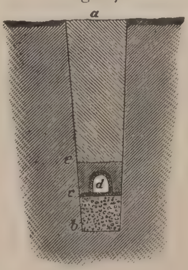
Thinning of Evergreen Conifer Plantations.—Although large masses of Pine, Spruce, and Silver Fir are somewhat sombre and gloomy in the immediate neighbourhood of houses, yet they are fine objects on undulating land in the middle distance or within an easy drive, their massive evergreen foliage rendering them effective at all seasons of the year. Evergreen Conifer plantations are often formed solely for ornament, independent of the quantity or the quality of the timber they may produce. Such plantations, whether pure or mixed, should only be made at a wide distance (not below 5 or 6 ft. from plant to plant), and should never be allowed to form close canopy, which would destroy the lower branches and mar the picturesqueness of the trees.

Dense coniferous plantations are never very ornamental; and owing to the comparatively small store of reserve nutrients the evergreen Conifers secrete, thinning does not usually overcome the defects of crowding so easily or so completely as is possible in the case of broad-leaved trees. But here also *cautious thinning, often repeated*, is the best means of making the trees more branching and ornamental.

The Thinning of Ornamental Broad-leaved Woods can, and should, be done with a far freer hand than is advisable in timber crops. If begun early and repeated from time to time, it causes the maximum of branches and foliage to be produced, thus increasing the ornamental effect both in summer and in winter, and at the same time it strengthens the tree-roots and diminishes the danger of windfall. But if ornamental plantations have been allowed to grow up close at first, thinning must be done very carefully else danger from windfall becomes much increased. Further, and especially in the case of Oak, any sudden clearance tends to induce flushing of shoots along the stem, and consequent stag-headedness in the trees left.

Covered Drains in Parks.—When drainage is necessary for the thriving of park trees, covered drains are preferable to ugly open trenches. Towards closed drains, however, even when laid very deep, the roots of trees are attracted because of the moisture, and it is therefore necessary to adopt some plan which may secure the efficiency of the drain, although perhaps allowing the roots to have access to the water to a certain extent.

Fig. 87.



Such a plan is shown in Fig. 87. The drain (a b) is 4 ft. deep, 12 in. wide at top, and 9 in. wide below. About 10 in. of broken stone or large gravel should be put in at the bottom (b), and above this a sole of slate laid down (c) to support the drain-tile (d). Between every two slates there should be a space of about an inch, so that if the water rises above the gravel it can find its way into the tiles. Good clay should be puddled above and at the sides of the tiles to a thickness of 3 in. (e), when the rest of the trench can be filled up again with the earth taken out. If the roots of trees near the drain find their way to it, they will naturally be attracted to the base of b, which will always be wettest; but even then the drain-tile (d) can easily carry off the drainage water after heavy rainfall, while the stiff puddled clay, from c to c, prevents the roots from reaching the drain-tile from above.

Temporary Nurseries for Park-Planting.—When ornamental planting and shelter-belts are being originally formed on farm or pasture lands, a good deal of planting is necessary, and in this case a small temporary nursery will prove of advantage. Its site should be chosen in a sheltered situation with a fresh, porous, loamy soil, and its extent will of course depend on the number of trees wanted (1815 plants going to the acre at 6×4 ft.)

When sufficient ground has been enclosed, the whole should be laid off in *nursery-beds* 4 ft. broad, with 2 ft. paths between, thus making the beds 6 ft. apart from centre to centre. A full spit of earth should then be taken from each alley and thrown on the nearest bed, thus deepening all the paths about 9 in. and raising the beds $4\frac{1}{2}$ in. About 2 in. of well-rotted leaf-mould should then be laid on the beds and slightly dug in, when they will be ready for receiving the stout young saplings, carefully selected from a public nursery. Only good healthy transplants should be selected, 4 to 5 ft. high for broad-leaved kinds, and $1\frac{1}{2}$ to 3 ft. high for Conifers ; and if they cannot be all planted immediately in the temporary nursery, they should be *sheughed* or temporarily bedded as near at hand as may be convenient. The plants should be put at 4 ft. apart in the centre of each bed, thus standing at 6×4 ft. (1815 per acre). The planting should of course be done with special care, in the manner usual in nurseries (see chap. iii. p. 377).

The paths, being lower than the beds, will act as drains ; but to prevent water lodging in them after rain, an open ditch should be cut along one end of the bed and paths, and should be carried away to empty itself some distance from the nursery. The beds should be kept clear of weeds in summer by frequent hoeing ; and the plants should be carefully pruned to have a good strong leader, and to keep side-branches well in check.

If the land is merely of average or inferior quality, slight manuring may be beneficial in autumn or spring ; but it should be confined to well-rotted vegetable-mould, or wood-ashes, or charred turf dug in very slightly, so as not to disturb the plant-roots. By careful tending in this way the trees will reach a height of about 12 ft. in half the time they would take if planted out at once, in place of being schooled in a nursery. The main advantage of placing the young trees on raised nursery-beds, instead of on level ground in the usual way, is the greater ease with which the plants can be lifted for subsequent removal, with all their roots attached.

Previous to planting the young trees in their permanent sites, the land where they are to stand should be drained, if not naturally dry ; and the pits made for the reception of the trees should be about 2 ft. wider and 4 in. deeper than the cubes or balls of earth containing the roots. As each pit is opened, a sufficient quantity of good compost-earth or light turf loam and well-rotted mould should be brought alongside of it and thrown in to a depth of 3 in. all over. On this the cube or ball of earth containing the roots of the tree should be carefully placed at its former level, and the vacant spaces at the sides filled up with the good rich soil. As each tree is planted it should be well watered about its roots, to settle the earth around them.

Transplanting Large Trees.—Transplanting, however, must always mean a certain amount of physiological disturbance ; while the larger the plants, and the more careless the method adopted, the greater must this disturbance be, and the greater must also be the difficulty the young tree finds in establishing itself in its new environment and carrying on the work of vegetation in a healthy manner. Hence greater care and attention have to be paid to the transplanting of large saplings 10 or 12 ft. high than is necessary for far younger plants. *Theoretically*, any tree, no matter how large or deep-rooted, can be moved successfully if one can raise with it a ball of earth containing all the roots and rootlets; but *practically* there are limits to human ability in that direction. Still, much can be done to prepare the roots for removal, and thus simplify the task in the case of fairly large trees.

No tree can maintain its health unless it has a normally developed root-system for imbibing food-supplies in the shape of the soluble salts obtained from the soil. But trees have usually good recuperative power by virtue of the reserve supplies of nutrients they store up each year in the form of starch ($C_6H_{10}O_5$), and which they can convert again into grape-sugar ($C_6H_{12}O_6$) for constructive processes when active vegetation recommences in spring. If necessary, these nutrient reserves can be used for recuperation when the organism is subjected to disturbing influences; and it therefore follows that any healthy tree deprived of a portion of its roots will recover its vigour if subjected to no further disturbance till the previous damage has been repaired; and in the case of a transplanted tree this means till it has established itself in its new home by forming a sufficient quantity of new roots to maintain the due balance between imbibition through the root-system, and transpiration of water and elaboration of sap in the foliage.

To deprive a tree of some of its roots, and at the same time transplant it, creates a double and very serious disturbance in the organism. If a portion of its roots be cut away, no permanent injury will necessarily follow if it have a sufficient reserve of nutrient and be allowed time to replace the lost roots without further disturbance meanwhile. In young vigorous plants both the accommodative power and the recuperative capacity are greater than in large trees, just in the same way as youth has an advantage over old age with regard to disturbances in the human organism. But in transplanting large trees the root-system must be specially prepared for removal, and practical experience has shown that this is best done by digging a trench round the tree at about two-thirds of the diameter of the spread of the branches—*e.g.*, if the spread of the branches averages 12 ft. in diameter (not including the extreme points of large limbs), the diameter of the ball of earth to be trenched should be 8 ft.

One can easily assure oneself of this by a simple test in a nursery, by cutting-in with a spade (to about 6 in. from the stem) the side-roots of a row, say, of Oaks about 5 or 6 ft. high, and leaving another similar row untouched. If the plants be examined at the end of a twelvemonth, it will be found that the small fibrous roots of the former are more numerous and better developed than the rootlets of the latter; and when the plants from these two rows are raised and transplanted, those specially prepared, by having their side-roots cut, are usually, *cæteris paribus*, healthier and grow more rapidly than those whose roots remained uncut till the time of removal. And it is on this principle that large trees should be prepared for transplanting. By cutting-in the side-roots previous to transplanting a tree, the development of a large supply of young fibrous rootlets is stimulated, which enables it to continue imbibing food-supplies when its organism is disturbed by transplanting; and the continuity of active vegetation can never be well maintained unless the tree has been previously prepared. The amount of disturbance to be resisted is of course greatly diminished by strong **pruning** of branches at the time of transplanting.

Such a preparation, in fact, consists of converting one violent major disturbance into two minor disturbances. And it stands to reason that the operations will be the more effectual, the younger and more vigorous the trees operated upon are—for beyond a certain age, varying according to the species of plant and its individual vigour, the accommodative and recuperative power becomes so weakened that transplanting must always be attended with great risk.

When large trees have to be transplanted they should, if possible, be taken from light, fresh, loamy soil, and they should be well pruned before being lifted. Trees growing on light loam are usually better supplied with roots and rootlets than those on either very light or stiff clayey soil. When a tree about 30 ft. has to be transplanted, one should be chosen with well-developed branches. A loose cord should then be fastened round the base of the tree and a circle described with it round the stem at 3½ ft. distance, so as to mark off a circle having a diameter of 7 ft. A 2-ft. trench should then be dug all round on the line thus marked out, and deep enough to go below the side-roots. All the roots severed should be pared smooth. After trenching to a depth of 2 ft. few roots will be found, and these only with few fibres; and such should be closely cut to make them produce small roots more plentifully. The ball of earth between the trench and the stem should be undermined all round, gradually sloping down from a depth of about 20 in. deep near the top to fully 30 in. deep towards the bottom of the ball. Care should, however, be taken not to create a severe disturbance by coming in contact with the tap-root, essentially necessary for the support of the stem until the shortened side-roots have thrown out fresh suction-rootlets for imbibing adequate supplies of food. The ball of earth should, therefore, merely be undermined to about 2 ft. from the perpendicular of the edge all round, and all loose pieces of soil should be removed from its sides with a small pick. The whole of the ball of earth should then receive a 9-inch thick coating of compost earth, formed of half-rotted vegetable-mould and an equal quantity of light peat-mould mixed well together; and when the ground-level is reached, about 6 in. of compost should be spread over the top of the ball. At the same time the larger branches should be shortened to about one-third of their length.

Trees growing in the close canopy of a plantation are not suitable for transplanting, as they are apt to throw out a flush of stem-shoots and become dry in the crown. When trees must be taken from a wood, they should be selected from thin and open parts, or from the edge of the wood, where they have had a free growing-space for the development of their branches and roots in at least one direction. And they should have a good, sound, thick bark, not apt to be affected by sudden change or exposure, or damaged by *sun-burn*.

On cold wet soil trees grow slower than on light dry land, for their root-system is not so good. In moving trees from stiff wet soil, the ground should therefore be drained about the roots before being treated as above described.

The bulk of the fibrous rootlets of trees are usually developed within the periphery of its branches,—unless in exceptional cases, such as the proximity of a drain or other watercourse, a stratum of more fertile soil than that in which the tree stands, a heap of manure, &c. The development of the side-roots may then become abnormally great, and extend far beyond the usual spread of the branches.[1] This may often be noted in the case of hedgerow timber, or of trees growing along the side of a wood next to a field.

Before lifting large trees, prepared in the above manner, **they should be well pruned,** and when isolating the ball of earth for transplanting, no part of the compost-earth put about the roots should be disturbed. This better soil should form part of the ball: it will easily adhere through the young roots pervading it. If moist, the new site should be drained; and where the soil is stiff, the hole should be made wider than the ball of earth, and filled up with loam and well-rotted mould, always favourable to the growth of roots and the development of rootlets. The error of planting too deep should be avoided, and more than 4 in. of soil should never be put over the top-roots even of large trees. When the ball of earth is very large, its mere weight is sufficient to keep the tree upright during high wind. The earth put about the roots should not be firmed so tightly as is often done, for this is neither necessary nor beneficial. When about 6 or 8 in. of earth have been put in around the roots at the bottom of the pit, a good watering should be given to associate the earth intimately with the roots; and the other layers should be also well watered, when the surface-soil should be well firmed, and then levelled, turfed, and watered. If the first summer after the transplanting be hot and dry, occasional copious waterings of the ground will assist the trees in establishing themselves.

The kinds of trees easiest to transplant are those having compact heart-shaped root-systems, and the above method of preparation is really an artificial way of inducing the growth of such a root-system. It can be applied to all kinds of trees; and even large Turkey Oak, Holm Oak, and Holly may thus be transplanted as successfully as Common Oak, Lime, or Elm.

Large trees from shady places transplanted into light and warm situations are apt to throw out a flush of stoles, or suckers may be thrown up from the roots, or adventitious shoots may break out along the stem and result in **stag-headedness** or atrophy of the crown. To check any tendency to stag-headedness and force the sap upwards, all young shoots should be removed, because if allowed to grow they will appropriate a large part of the sap in ascending, and must consequently deprive the top branches of their necessary supplies of mineral food and water.

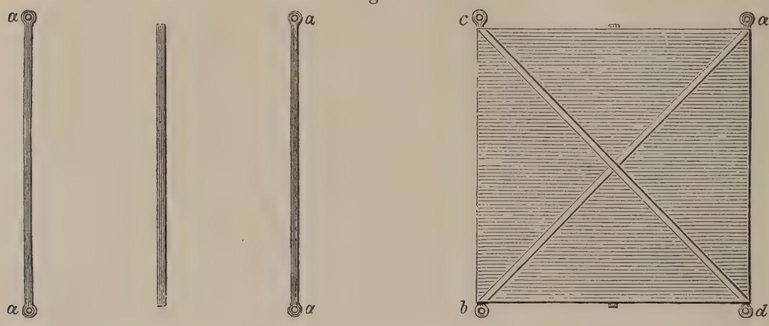
Transplanting Machines for Small Trees.—When the whole weight involved is only about 1 to 2 tons, and can be dragged by two horses, only a small flat sledge, made of thick sheet-iron and supported with iron bars, is needed (Fig. 88).

The frame consists of three bars of iron about 5 ft. long, $1\frac{1}{2}$ in. broad, and over half an inch thick. The two outer bars (*a a*) have holes at each end for attaching the hooks of the dragging-chains. These bars are covered with a piece of strong sheet-iron, 5 ft. square, firmly nailed to them; and to keep the sledge firm when carrying a heavy load, two iron cross-bars, of the same strength as the others, are fixed diagonally on the upper side above the sheet-iron (*a b*, *c d*). With this very simple contrivance trees of nearly 4 tons weight may easily be removed by a pair of horses.

[1] In the S.W. of England I have seen Elm-roots stop the plough at a distance of 35 yards from the bank-and-ditch hedge in which the trees were growing.

As the sledge is thin and strong, it is comparatively easy to get it under the ball of earth by undermining this first on the side from which removal will take place, and then upwards under the ball to give the bottom of the hole a slight upward slope, so that when the sledge is put under the ball and the other sides are being loosened, the mass of earth can be drawn down the incline formed by the sledge and brought well on it. The tree can then be firmly fixed by ropes reaching from about 8 or 10 ft. up the stem to the four end holes of the bars of iron, to

Fig. 88.



which also the hauling-tackle is attached. Before pulling the tree on the sledge, the earth on the outer circle should, of course, to make an easy incline for hauling, be dug away where the sledge is to enter. On reaching the pit prepared for the plant, it should be pulled into position down an incline on one side; and when the guy-ropes have been untied and the ball eased, the sledge should be pulled out by an incline on the opposite side.

Transplanting Machines for Large Trees.—For the successful removal of large trees, a machine of greater power is necessary to convey the whole tree and the ball of earth containing the roots in an upright position. Many different kinds of such machines are in use, but description will be limited to two good practical kinds, the first of which was used extensively at Kingston Hall, near Derby.

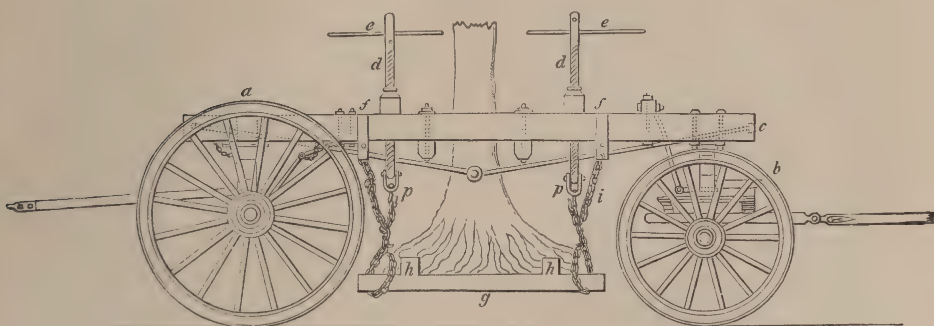
(1) **The Kingston Machine** consists of two pairs of wheels, each working upon a strong axle (Fig. 89). That used for transplanting trees up to 25 ft. in height is capable of standing a weight of about 5 tons, and that for transplanting trees of 30 to 40 ft. high can bear a dead-weight of 10 to 15 tons, drawn by 4 or 5 pairs of horses.

In the larger machine, each pair of wheels is about 9 in. broad. The front wheels (*b*) are 5½ ft. and the back wheels (*a*) 7 ft. in diameter, whilst the length from axle to axle is about 15 ft. On each axle a strong frame is placed to raise the horizontal bearers to a convenient height and to make the whole machine easier to work (*k*, *l*). The front frame turns on a horizontal wheel (*m*), as in a carriage. Two strong wooden beams (*c*, *n*), about 10 in. deep by 6 in. broad and parallel at about 2 ft. apart, rest upon the frames, and are fastened to them by strong iron bolts, unscrewable as occasion may require. Placed across and above these horizontal beams are two other short beams (*o*), into which the jack-screws (*d*) are fixed for turning by cross-handles (*e*). Strong chains (*p*) are attached to the lower ends of the jack-screws, and by means of those the tree is chiefly raised, assistance being also given by side-chains fastened to strong iron rings (*f*) fixed to the beams, and made to act along with the others attached to the screws in sustaining the weight of the tree and the ball of earth during the reversing of the screws for a new hold. The horizontal planks (*g*) on which the ball of earth rests are supported by the chains, while two cross pieces (h) placed on the horizontal planks help to support the ball. All the pieces should be made of the best Oak, and should not be less than 4 in. thick.

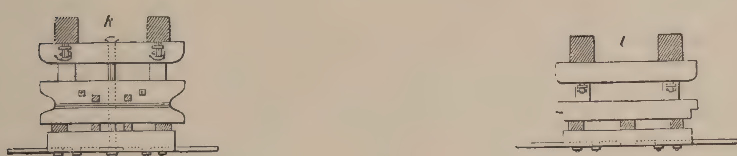
The *modus operandi* is as follows :—

The ground around the tree was cleared, and at 4½ ft. from the stem of the tree a circular cutting was made to the depth of about 3½ or 4 ft., and about 2½ ft. in width. This done, then on the most open side of the tree a sloped cutting was made from the surface of the ground to the bottom of what may now be called the ball of earth, and a similar sloped opening was made on the opposite side of the tree. The first of these sloped cut-

Fig. 89.

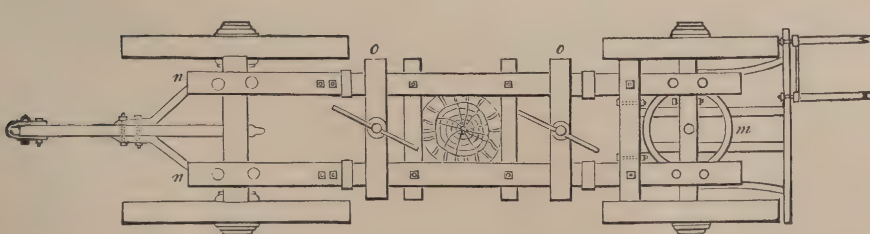


Side elevation.



End section. End section.

Framework resting on the axles.



Ground-plan.

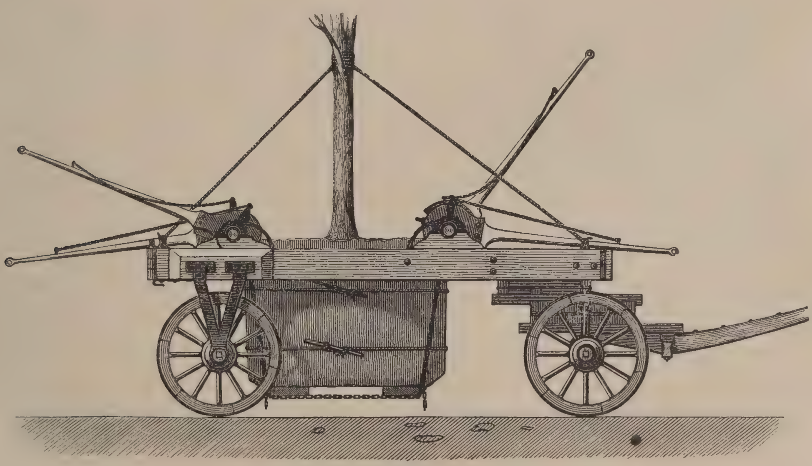
tings was made for the purpose of drawing out the tree up this slight incline to the surface of the surrounding ground. The circular opening in the earth around the tree, and the two sloping roads on each side, being now prepared, the workmen commenced to undermine the ball of earth : this being done all around, four stout oak planks, long enough, were placed under this ball of earth in front and behind—that is, crossways to the direction of the machine ; and under these two others were placed lengthways, with their ends in the direction to back and front of the machine. It will now be understood that these four oak planks under the ball of earth cross each other at their four extremities ; and around their extremities, at each of the four corners, four sets of strong iron chains are fastened. A reference to the diagrams given will assist in explaining this.

The first set of chains brought into play were those attached to the bottom of the jack-screws. Being made as tight as possible over the ball of earth, they were then hooked on the end of the jack. The two jacks were then turned by two or four men each, as the case might require, until the tree and the ball of earth were raised from the ground about 6 or 10 in. The jacks were then permitted to rest, and what is called the side-chains were put in requisition. These, as we have already stated, are fastened to the planks under the ball of earth at the same point as the others, the opposite ends being made fast to the side beams, as shown in the engraving. This being done at the four corners, the jacks are reversed, and the first set of chains slackened; the weight of the earth and tree is then sustained by the side chains. The first set of chains are again adjusted, and made as tight over the ball of earth as manual power can effect. The jack is then run down, and again attached to the chain at the lowest point it will reach. The jacks are once more applied, and run up till the end of the screw has been completely worked up to the under side of the cross beam on which it rests. By this second lift the jacks have probably gained upon the 6 or 10 in. which they made at the first lifting, and the bottom of the ball is now 15 or 20 in. from the ground. The side chains, which are now quite slackened by the second lift of the jacks, are again made as tight as possible: this accomplished, and all securely and equally fastened to the side beams again, the jacks are gently reversed, till the weight is equally divided betwixt the side chains and the jack chains. The tree is now in a condition to be drawn out, unless it should be necessary to give it a third lift with the jacks, so as to raise it still higher from the ground; and if so, the side chains must always be attended to, as already described. They may be properly called the guard-chains, as they prevent accidents in the event of breakage of any of the jack-chains, when the former would take the weight of the tree, and prevent its falling. About 10 or 15 ft. up the stem of the tree four ropes extend from this point to the two front and two back corners of the machine; and this is all that experience has found necessary to preserve the tree in its perpendicular position during its transport on the machine to its future place of growth. The perpendicular position of the tree is, however, very greatly secured by the four side or guard chains. We have now to describe the mode of introducing the stem of the tree within the machine. This is effected in the following manner: The machine is drawn as near to the tree as circumstances will allow; it is then taken to pieces by unscrewing the different bolts—that is, the main horizontal beams are unfastened, and thrown over the wheels on either side. The larger hind-wheels are then placed in their proper position on the sloped cutting behind the tree, and the smaller fore-wheels on the sloped cutting before the tree; the large beams are then lifted on to their places, one on either side of the tree, and made secure with the iron bolts and the requisite fastenings. The tree then stands with its stem betwixt the side beams, and with a pair of wheels behind and another before. The chains and jacks are then applied as already described, and thus the process is complete. The next and only point deserving further allusion is that of planting or placing the tree where it is ultimately to grow; and this is effected in the following way: The hole, sufficiently large to receive the ball of earth, is dug to the necessary depth; then, on the opposite sides of the hole, a sloped cutting, wide enough to admit the machine to be drawn down and through it, is also provided. Into this cutting, therefore, the machine and tree are drawn, and through it the team of horses must first pass. When the tree has reached the proper point, the machine is permitted to rest; props of brick or stones are then raised at the four corners immediately under the ends of the cross planks. These props may be three or five bricks in height; and when all is prepared in this way, the jacks are reversed, and the ball of earth is gradually lowered down till the ends of the cross planks rest upon the corner props, and the tree has taken its proper perpendicular position; and this is effected by the raising or lowering of these corner props. All being adjusted, any opening that may remain between the bottom of the ball of earth and the bottom of the hole provided for the tree is filled up with earth—the whole being made firm around and under the roots of the tree. The brick or stone props are then struck out, and the planks removed—a process easily effected, as the tree now rests upon the earth which has been placed under and about it. These planks are, however, well ironed at each end, so that, in case of any difficulty in their removal, a horse or horses may be readily yoked, and the planks withdrawn (Brown, *The Forester*).

(2) **The Parisian Machine.**—The French employ a different kind of machine (Figs. 90, 91), whose lifting-power is obtained by the use of levers and rack-wheels. Though perhaps not so powerful as the Kingston machine, it does well for any but very heavy weights. It is thus described in Robinson's *Parks, Promenades, and Gardens of Paris*:—

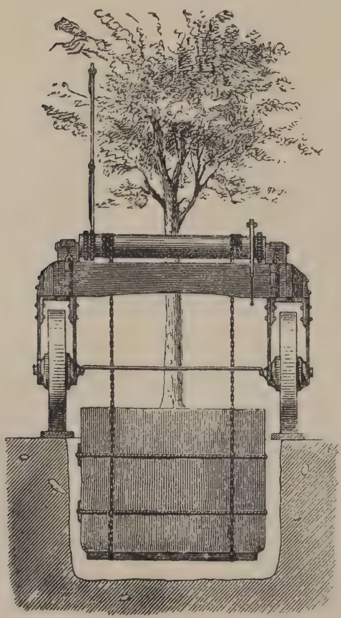
We take, for example, a specimen tree, 30 years old, 30 ft. high, the trunk of which has a circumference of 3 ft. at a height of 3 ft. from the ground; its total weight, with the earth-ball, being nearly 2 tons. The operation is commenced by staking out, round the stem, the circumference of the earth-ball, which will be, on an average, about 4 ft. in diameter for most species, and larger according to the size of the trees to be removed. A second concentric circle is then made about 2 ft. outside the first, the space between which will be the place for the trench to be dug for preparing the tree. The soil is then removed from this trench to the depth of 3 ft., and the small and delicate roots are drawn out of the earth, left hanging, and carefully preserved. The earth-ball is then undermined, to prevent the roots from adhering to the subsoil; two thick planks, a foot wide, and a little longer than the ball, are placed underneath parallel with the width of the cart,

Fig. 90.



so that they sustain the weight of the earth when the tree is lifted. Privet stems are now placed vertically, close together, all round the earth-ball, tied at the top and bottom with ropes, so as to prevent the earth from crumbling away, and also to protect the small roots from the inclemencies of the weather. The removal of the tree is then commenced in the following manner: Two stout thick planks, strong enough to support the cart with the tree slung in it, and a little longer than the entire excavation, and having iron plates about 2 in. higher than the surface, bolted on each side so as to prevent the wheels from slipping off, are placed, parallel to each other, across the excavation, with the exact width existing between the wheels. The movable bars at the back of the cart are then removed, and the cart is backed into the ways until the trunk of the tree is exactly in the centre of the frame. The movable bars are then put in their place again, so as to strengthen the back of the wheels, which do not run on an axletree, but are fitted in wrought-iron frames hanging from the upper part of the cart, as shown in Figs. 90 and 91. The chains attached to the rollers on each side of the cart (as shown in Fig. 91) are now lowered, and passed under the planks before described, which are placed under the earth-ball. When all is fast, four workmen begin simultaneously to turn the handles attached to the cast-iron cogwheels, by which great power is obtained on the rollers. The tree is raised slowly and steadily until it just swings clear of the ground, and then nothing is left to be done but to steady the tree before it is hoisted up to its proper height. For this purpose there is at each corner of the cart a strong *wrought-iron* hook, to which is attached a block, through which runs a strong rope fixed at the other end to a leather collar. These four ropes are then raised up together, and the collar firmly fastened on the stem of the tree about 7 or 8 ft. from the top of the earth-ball. The tree can now be easily removed without fear of its falling over.

Fig. 91.



The horses are then attached to the cart, which is drawn slowly off the ways, and the tree can be removed with safety to its future resting-place. If the tree be vigorous and healthy, a hole a little wider than the one from which it has been removed should be dug beforehand: the earth, being placed carefully on one side of it, should be of a kind to suit the tree about to be planted; and if not, it should be replaced by suitable soil. [The hole being in readiness, and suitable soil being prepared for the tree,] the planks or ways are placed in position, as before described, and the cart is very carefully drawn on them until the earth-ball is exactly in the centre of the hole. The tree is then slowly lowered, and when it touches the ground, the guy-ropes from the corners of the cart are pulled tight, so as to have the tree perfectly upright and steady; the chains are unfastened and hoisted up round rollers; the two planks beneath the earth-ball are undermined and removed, and the privet-shoots taken off. They then proceed to fill up the hole, particular attention being paid to the small roots, which are each separately covered in. When this is finished, and the tree is considered sufficiently steady, the ropes are removed, the bars are taken out of the back of the cart, which is drawn away, and the bars having been refixed, all is ready for another removal.

The Raising of Fallen Trees.—As windfall trees are usually thrown only when the soil is soft and sodden with rainfall, the root-system generally tears up along with it a large mass of earth, within which the rootlets are numerous. There is, therefore, in the operation of raising blown timber less disturbance than when the displacement is artificial (as in transplanting). But prompt action should be taken to raise the trees in their places in an upright position, and they will thrive again if the work be properly done and precautions are taken to prevent the wind swaying them too much.[1] To make complete recovery possible in the case of large trees, judicious **pruning** of the crown is necessary to restore the balance between imbibition by the root-system and transpiration through the foliage when the flush of new leaves takes place in spring.

Best Season for Transplanting.—The best time for transplanting large

[1] A notable instance of this was the restoration of a fine old Lime-tree avenue at Duns Castle, Berwickshire, after many trees were thrown by the Tay Bridge gale at Christmas 1879. The largest tree raised was 12 ft. 6 in. in girth at six feet from the ground, and was computed to contain 300 cubic ft. of timber while the trees varied in height between 70 and 80 ft.

deciduous trees is in October or March, as the inevitable disturbance is then reduced to a minimum. Trees moved during the winter months do not imbibe water so readily for the spring flow of sap; hence they often receive a check late in the season, and sometimes this retards their growth for one or two years.

Large evergreen coniferous trees should, however, be transplanted just when the buds are beginning to open in April, because the trees have then the maximum of sap and of nutrient reserves. If occasion requires it, however, they can be transplanted any time from October till the middle of May. Indeed, in places with habitual rainfall throughout the summer (as in parts of S.W. Ireland) both planting and transplanting can be done with less risk in July and August than in the much drier spring or autumn.

Practical experience in most parts of Britain has shown that when large evergreen Conifers are transplanted in autumn, the winter winds shake the trees and disturb their roots so that they have not so fair a chance of establishing themselves as when moved in spring after the usual time of heavy gales has passed. Thus large Conifers transplanted in autumn generally **wilt** for a year or two after, and make little or no progress till their roots have established themselves and laid hold of the soil; and this is slow work after a serious check from heavy winter winds.

Stimulating the Vigour of Old Trees.—The best way of resisting nature in cases of senile decay is simply to feed the root-system artificially by manuring, and at the same time to prune the branches for the purpose of reducing the foliage—*i.e.*, of lessening the number of leaves that have to be provided with food. With such reduced quantity of foliage the root-system can usually, notwithstanding its decreased activity, satisfy the demands made as to nutrients for assimilation and as to water for transpiration. But the work of recuperation may be greatly assisted by removing the turf and giving the soil a top-dressing of fresh bullocks' blood, or of compost-earth, or of artificial manures, the nutrient salts contained in which will be washed by rainfall down to the rootlets. This will not only feed these, but will also encourage the formation of fibrous roots, unless the trees are past the age when recuperation is possible.

The method that used to be recommended by Brown (*The Forester*) was somewhat as follows: When an ornamental tree is declining in health, all dead branches should be cut away till only healthy wood appears at the cut parts.[1] The stem of all the larger branches should be scraped and cleared of moss, and well scrubbed from top to bottom with a brush and cold water to free the bark from dirt. Then a trench should be opened all round, cutting the roots in the same way and at the

[1] It may here be noted that when branches are being removed, either close to the stem or at any distance whatever from it, by means of the pruning-saw, this should be applied first of all at the lower side of the branch; and only when the bark and the outer sapwood there have been well cut through should the saw be applied above in order to sever the branch. Otherwise, in falling, the weight of the cut portion tears away the bark from the lower part of the branch below the cut; and this not only retards the cicatrisation of the wound, but also offers a larger surface for the entrance of disease-producing fungus spores.

same distance (two-thirds of the average diameter of the tree-crown) from the stem as if preparing the trees for transplanting; but here a drain should be made at the bottom of the trench to prevent water from collecting there and stagnating. Supposing the roots have been cut all round at 6, 8, or 10 ft. from the stem, thus making the diameter of the ball of earth respectively 12, 16, or 20 ft. according to the size of the tree, then the trench opened outside the ball should be 3 to 6 ft. broad and deep enough to cut through all the side-roots. The good soil thrown out of the trench should be laid on the outer edge, so as to be ready for mixing with any compost-earth to be afterwards put in. All earth of inferior quality should be immediately carted off before beginning to fill in the trench with earth consisting of equal parts of the better soil (already laid on the edge) and of leaf-mould, with a little powdered lime to assist further decomposition of the humus. The filling in of new soil should proceed in layers, each being well watered and then firmed by treading lightly. When the trench has been completely filled, the turf may be pared from the trench to the stem to a depth of 4 to 5 in., and thrown on the top of the new soil; and a layer of compost-earth may be spread over the whole ball to the outside of the trench, and raising it to about 8 in. above the level of the ground beyond. The whole operation is then completed by a good watering and firming of the new soil.

A healthy state of the trees is encouraged by occasionally syringing the foliage and cleaning the bark with a brush and cold water in summer; and during continuous dry weather watering of the new soil assists in the formation and work of young roots.

From a physiological point of view this expensive method of treatment is, however, open to the very obvious objection that any such disturbance of the natural balance between imbibition through the root-system and transpiration of water and elaboration of sap by the foliage should be avoided when trees are, through senile decay, approaching their limits of physical vigour.

Prevention of Decay in Wounds and Holes.—Holes caused by wounds are often to be found on old park trees. When a piece of bark is removed from the stem, through accident or otherwise, the part exposed loses its vitality, dies, and is liable to become infected with fungi. If the injury be not extensive, the uninjured living cells surrounding the exposed spot will soon begin to form callus growth, which will gradually close over the wound; but if the damage be extensive, the wound-surface naturally remains longer exposed to risk of infection, and a rotten cavity is formed before the surrounding healthy tissue has had time to form callus growth to cicatrise or occlude it. **Wound-rot** may also, however, set in without the presence of fungi; but, as a rule, either saprophytic or parasitic fungi assist in the more rapid decomposition of the dead woody tissue. The holes also harbour noxious insects whose larvæ feed upon decaying wood, and this of course hastens the process of destruction.

When an old tree is thus injured, the wounded part should at once be protected from the action of the air and of the weather. The simplest and best way of doing this is to apply a good thick coat of tar with a brush. This antiseptic coating will prevent fungus spores from effecting an entrance, and will keep off insects, while it does not interfere with the process of cicatrisation. If the tree be old and the wound be large, however, its occlusion by cicatrisation can hardly be expected. But at all events the coating of tar will hinder fungus spores from entering the wound-surface, and will prevent the formation of any cavity, thus contributing very materially towards enabling the tree to remain sound and healthy.

Where decayed holes are found on old trees, they should first be well cleared of rotten wood until none but healthy tissue is to be seen round the walls of the cavity. The hole should then be completely filled with pitch, which not only acts antiseptically in preserving the wood, but also prevents noxious insects from lodging in it. To hide these black spots a piece of bark, as nearly as possible of the same colour as that of the tree, should be nailed neatly over the hole. Or where no great weight is attached to outward appearance, the hole may be well filled with Portland cement. This acts in much the same way as pitch. Neither the pitch nor the cement possesses any *curative* property; but by shutting out light, air, moisture, warmth, and organisms of any description (fungus spores, insects, &c.), they arrest further progress in the decomposition of the woody-fibrous tissue, and hinder the infection by parasitic or saprophytic fungi.

Tree-Guards.—In order to protect ornamental trees from injury by cattle grazing in the park where they are planted, the trees should be fenced in some way, for a time at least. When the trees have outgrown such danger, the fencing should be removed, for a fenced tree is not a picturesque object.

There are many kinds of **tree-guards**, varying in appearance from a simple wooden post-and-rail to the neat and often ornamental iron fence.

Wooden tree-guards have of late years been much superseded by wrought-iron guards, such as are advertised by many firms, though these are too expensive for use on any very extensive scale. Where large operations are on hand—*e.g.*, along lines of broad-leaved trees fringing coniferous crops, or where comparatively rare species of trees have been planted in places where cattle or deer roam—the simplest and cheapest method is to bind furze, thorns, or other brushwood round the stem and fasten this securely with wire (barbed or smooth).

Hedges and Fences.—As the hedges and fences on an estate are usually under the forester's charge, it is necessary that he should know something about the best kinds of hedge-plants and their management.

Form of Hedges.—The form in which hedges should be trained depends on the situation, on the object in view, and on the taste of the proprietor. There are four forms generally adopted—*wedge-shaped*, *full-sided*, *square*, and *upright.*

(1) **The Wedge-Shaped Hedge** (figs. 92, 93) is the best for any high-lying district with heavy snowfall, and it is by far the simplest to maintain. In high-lying situations hedges are often injured by snow lying upon them, and the wedge form minimises the perpendicular pressure. This shape of Hawthorn hedge is usual throughout Great Britain in all the high-lying agricultural districts.

(2) **The Full-Sided Hedge** (fig. 94) is the most common form in well-sheltered districts. Owing to its bulging sides cattle cannot easily approach and injure it; but it needs to be well maintained and carefully looked after. It is less adapted than the wedge-shape for a high-lying country, because its bulging sides are apt to be crushed by snow.

(3) **The Square Hedge** (fig. 95) is purely ornamental, and only suitable for gardens and policies, because it is liable to become straggling, interrupted, and useless as a fence.

Fig. 92.

Fig. 93.

(4) **The Upright Hedge** (Fig. 96) is also only suitable for pleasure-grounds and home parks.

In choosing the form of a hedge for agricultural and arboricultural purposes, the first points to consider are use and economy rather than ornament, and from the practical point of view the wedge-shaped and the full-sided hedges form the

Fig. 94.

Fig. 95.

best fences, while the other two are ornamental forms well adapted for producing extra shelter in pleasure-grounds, where they can receive constant care and attention.

(1) **Hawthorn.**—There is no fence more ornamental or more generally in use in agricultural districts than the Hawthorn hedge (*Cratægus Oxyacantha*), and it is certainly the best where a neat appearance is desirable. It should be well pruned at time of planting, as this stimulates its rate of growth at first. The Thorn hedge thrives best and lives longest on a heavy loam or clay soil. On light soil it does not grow so well, and sometimes dies suddenly; and there it is often mixed with Beech.

Fig. 96.

It is not unusual to see Beech mixed with Thorn as a hedge; the mixture makes a pleasant-looking hedge, but Beech itself is not a terror to live-stock in fields. The Sweetbriar (*Rosa canina*), too, is frequently mixed with the Thorn, and no doubt imparts a delightful perfume to the air after a shower in summer; but it soon overcomes the Thorns near it. The Crab-apple (*Pyrus malus*) also displaces Thorns in hedges. We have only to view the hedges in the southern counties of England to be convinced of the noxious effects of intermixing other plants with the Thorn (Macdonald's edition of Stephens's *Book of the Farm*, 1893, Div. V., p. 219).

(2) **Beech** makes a good hedge on exposed situations and on light soil. Under careful management, it can be kept in good and ornamental condition when dykes and palings of the same age are becoming useless. On many estates there are good Beech hedges at over 900 ft. elevation, where a better fence is secured by using the hardier Beech alone than by mixing it with Thorn. If any mixture be then desired, a sprinkling of Hornbeam may be put to the Beech, especially if the soil be moist. A Beech hedge should not be pruned or trimmed till the year after planting, else the plants are apt to die.

(3) **Whin or Furze Hedge** (*Ulex europæus*) is often to be found as a plantation-fence in Scotland and Ireland. But it cannot be recommended, as it harbours rabbits, and is apt to be injured by severe winter frost. Wherever a Furze hedge can thrive, a Beech hedge would probably be preferable from every point of view; besides which, Furze is a weed to be extirpated, rather than encouraged, in the vicinity of plantations.

(4) **Holly** (*Ilex Aquifolium*) makes a good ornamental evergreen fence where required as a screen or for shelter; but it is not a strong fence against cattle in fields. The Holly grows well under shade, so that it can be used for a hedge in situations where few other plants would succeed. To grow well, however, it requires a good, dry, light loamy soil, with plenty of well rotted leaf-mould.

(5) **Common Portugal Laurel** (*Cerasus Lusitanica*) also makes a very ornamental evergreen hedge, but only in sheltered situations. It is accommodating as to soil, so long as the situation is sheltered from cutting winds. For small grounds, an outer fence of Thorn and an inner hedge of Laurel are often very effective. The Thorn-hedge shelters the inner hedge of Laurel, and the latter remains in full leaf during the winter. In such cases sufficient space must, of course, be left between the two hedges to admit of easy trimming and tending, and to give each of them full exposure to sunlight.

(6) **Common Yew** (*Taxus baccata*) is also well suited for ornamental hedging, though of no use as a fence, because of its naturally slow growth, and its inability to resist large animals. Another well-known objection is that its leaves and berries are poisonous to cattle. It thrives best on limy soil, and can stand much shade. It also bears clipping well, and is therefore often utilised for fantastic or "topiary" gardening.

(7) **Boxwood** (*Buxus sempervirens*) is likewise well adapted for ornamental hedging.

(8) **Privet** (*Ligustrum vulgare*), a plant of rapid growth, is in some respects well suited for hedging. But it does not make a strong fence. It is too soft and yielding to resist pressure, and it is of so free and rambling a habit that it needs a good deal of attention to keep it in order. It is useful, however, for filling gaps in old Thorn hedges, where it is sometimes difficult to get any other plant to grow. It is only necessary to dig out the old roots of the dead Thorns and insert young Privet roots instead, say at 6 in. apart.

(9) **Barberry** (*Berberis vulgaris*) is frequently used for hedging; but it does not generally answer well, as it is apt to die under the heavy pruning indispensable to hedges. Further, it tends to propagate the smut on wheat (due to the fungus *Puccinia graminis*). Wherever the Barberry occurs on agricultural land, it should therefore be rooted out.

(10) **Hornbeam** (*Carpinus Betulus*) is a shade-bearing plant, surpassed only by Hawthorn and Beech for hedging purposes. Excellent Hornbeam hedges may often be found on fresh, light, sandy soil, where Thorns would not thrive.

(11) **Birch** (*Betula alba*) is sometimes found forming hedges on poor thin soil having a high altitude. It stands pruning well, and when properly looked after it makes a fair fence.

(12) **Elder** (*Sambucus nigra*) is used for hedging in the North of Scotland. Its hardiness and quick growth are its only good qualities, as it is ill suited for giving shelter in winter and spring. As a hedge plant, even for high and exposed situations with poor soil, Beech, and even Birch, is superior to Elder. But when a quick screen is wanted on an exposed part, it is preferable to most other plants for this special purpose, as it can grow from 4 to 6 ft. in one season.

(13) **Myrobella** or **Cherry Plum** (*Prunus Myrobalana*) forms excellent hedges. It grows well on poor soil, stands cutting as well as the Hawthorn, and thrives within the influence of the sea-breeze.

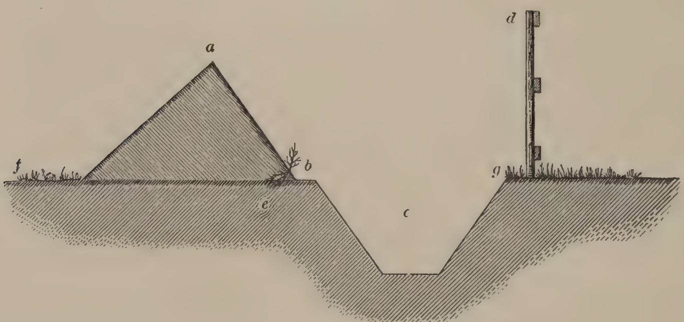
(14) **Hedges of Spruce, Silver Fir, and Juniper** all answer well for ornamental purposes, as they stand cutting and look well throughout the winter; whilst, as shade-bearing species of trees, they maintain considerable density. Constant trimming is needed to prevent them sending up leading-shoots.

Wooden Palings have often to be used as temporary fences when young hedges are planted where cattle are grazed in the adjoining fields. Horizontal palings are mostly used for agricultural purposes, and Larch is the best wood for this class of fencing,

Hedge Planting.—November is usually the best time for hedge-planting, and next to that February. But in either case the ground should be prepared in early autumn for receiving the plants.

Bank-and-Ditch Hedge (Fig. 97).—In planting a bank-and-ditch hedge, the line of the hedge is first marked off by pegs, then the measuring-line is stretched

Fig. 97.



Bank-and-Ditch Hedge.

a. Top of bank; *b*. Slope of ditch; *c*. Ditch; *d*. Temporary fence (paling); *e*. Base of bank; *f*, *g*. Ground-level.

about 6 in. on the outer side of where the hedge is to run. The surface is then levelled and cleared of weeds to a breadth of about 2 ft. as far as the line stretches, and the edge of the ditch is marked off with the common ditching-shovel. The digger faces the ditch side, and with his foot forces the spade deep into the ground, cutting the surface exactly along the stretched line. The cuts should not be perpendicular, but with the slope to be given to the side of the ditch, as shown downwards from *b*. When the cutting of one side has been completed, the line is shifted 4 ft. to the opposite side, and the other side of the ditch is formed (as at *g*), the digger of course making the second cut parallel to the first; and he must again face the ditch when digging. Both sides of the ditch being marked off, the turf, already cleared of weeds, is raised with the spade and turned upside down (as at *e*) on the bed levelled for planting the hedge. In doing this, about 6 in. (called the

scarcement) must be left between the bed and the edge of the ditch to support the bed firmly and prevent loose earth from rolling down the bank (*a*) into the ditch (*c*). In lifting the soil from the ditch, the bed must be kept 6 in. back from the edge; and in preparing the bed for the young plants, it must, on the outside, be made 3 in. above the level part or scarcement, and must slope back from the outer edge at an angle of about 45°, so that the roots of the plants may get easily down into the earth, while their tops stand well up.

The mound, bed, and scarcement being completed and cleared of weeds, the plants are put in. Hawthorn, Privet, Elder, and Myrobella should be carefully trimmed with the **Pruning-shears** (*not* chopped with an axe), so as to leave only about 4 in. of the stem of each plant; but no pruning or trimming should be given to Beech, Holly, Portugal Laurel, Yew, Box, Hornbeam, or Birch, otherwise they often fail to establish themselves. But Beech plants of from 8 to 12 in. high may easily be used for hedging. Taking the plants in his left hand, the planter with his right hand leaves them about 10 in. apart along the prepared bed, and so that the top part may project about 2 in. over the outer edge of the bed.

While the planter is doing this another man follows him, collecting the finest earth from the ditch and covering the roots of the plants with it, while taking care not to displace them. A third man follows and adds a spadeful of earth from the surface of the ditch to that put by the second man. As this will be enough to cover the roots, the whole of the soil is lightly firmed with the feet to secure the plants in their place and bring the soil in intimate connection with the roots. The ditch is then dug, and the earth thrown out forms the bank above the roots of the plants (as at *a*). The ditch is generally 4 ft. wide at top, 15 in. at base, and 2 ft. deep; and the size of the bank made with the earth taken out will be nearly 2½ ft. high and about 4 to 4½ ft. wide at base, the bank being given nearly the same slope as the side of the ditch. But as it is formed of loose earth, it is better to keep the bank slope a little lower than that of the ditch; and to prevent loose earth rolling back, it should be tramped down as work proceeds, receiving at last a firming with the back of the spade to keep it smooth and secure. The level scarcement should be left clean and neat, the tops of the plants should project regularly, and the soil be made firm about them. When the whole line of hedge is thus formed, a fence (*d*) is put up outside the ditch to protect it from cattle, and this paling or wire-fence must be kept in good order for about seven or eight years till the hedge itself becomes a proper fence. This method is well adapted to wet or undrained land.

Simple Trenched Hedge.—Another and cheaper method, only suitable for dry or well-drained land, is simply to plant in the line of fence. The ground should be trenched 4 ft. wide by 2 ft. deep along the required line, and all root-weeds should be carefully picked out, as their eradication afterwards disturbs the plant-roots and checks their growth. When the whole length of the intended hedge has been trenched and cleaned, it is levelled by eye. When the ground seems nearly level, the line is stretched tightly along the middle of the hedge-line to see if the bed be really level or not,—for where the ground is hollow the line will be above it, and where the ground is high the line will either touch or lie close to it. While the line is thus set the planter should mark time sideways along it, keeping the cord under the hollow of his feet, and treading down the soil firmly within about 5 inches on each side of the cord. On reaching the end of the line, still left on the ground, any depressions caused by the treading are filled with fresh soil, and beaten down with the back of the spade, so as to make a level bed about 7 or 8 inches broad on one side of the line, and 2 or 3 inches on the other. An opening is next made to a depth of about 9 or 10 inches with the spade upon the narrow side of the line, care being taken to make the opening parallel to the line. The plants are then put in along the side of the firm level edge, the earth is filled in, firmed, and made level.[1]

It may be remarked as to these two methods of hedge-planting (the descriptions of which are here abbreviated from Brown, *The Forester*), that by the latter the plants come sooner to useful size than when planted on bank-and-ditch. It is therefore the more economical method, and it has also the advantage of taking up less land.

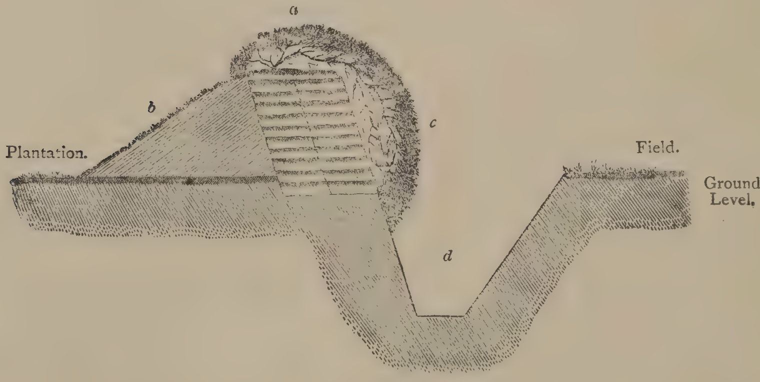
In preparing soil for hedge-planting on poor land, good earth should, if possible, be added, otherwise the hedge will spring up unequally. The best way is to cart fresh good loam from a distance, and mix it well with the poorer soil along the run of the hedge. Lime is sometimes applied to the hedge-bed, and when used in moderate quantity on strong or humose land it stimulates the growth of the plants ; but no other manure should be applied.

Hedge-plants should always be put at about 10 to 12 inches apart. Plants put in too close grow up weakly, and soon exhaust their strength ; while those set wider than 1 ft. take too long to close, and seldom make a thick fence.

Planting two rows of Hawthorn soon gives a good close hedge, and especially if coppiced close to the ground when about finger-thick.

Furze-hedges are usually planted as shown in Fig. 98, where *d* is an open ditch about 4 ft. wide at top and sloping to about 1 ft. wide at the base. The slope is steeper on the plantation side than on the field side, so as to make the ditch act better as a fence. The ditch is made about 3 ft. deep from the ground-level, and the turf taken from the surface is built up on the plantation side to about 2 ft., making the fence altogether about 5 ft. high. To make the turf-built part secure, it is about 2 ft. thick, with the

Fig. 98.



same backward slope as the side of the ditch below. The earth from the ditch is banked firmly above and behind the turf (as at *b*), and the furze seed is sown in April in a line along the top (as at *a*) about 18 in. back from the upper edge of the turf fence. The young plants are cleaned and weeded, and thinned out here and there if they stand too thick, during the first two years. During the third summer, when they have become fairly strong, they are dressed with the switching-bill, the cut being made in the direction *b a c* to *d*. By this means the young shoots are made to grow presenting all their points to the field.

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[1] Additional information about hedging, from the agricultural point of view, will be found in Macdonald's edition of Stephens's *Book of the Farm*, 1893, pp. 215-230. See also article on *Hedges and Hedge-making* in *Jour. of Roy. Agri. Socy. of England*, March 1899, pp. 87-116.

Pruning and Tending of Hedges.—Rash pruning at time of planting or too soon after it, and interfering with the roots by digging, are often the cause of hedges remaining weakly and dying off. Hawthorn, Privet, Elder, and Myrobella may be trimmed both at time of planting and once a-year after that, although it is often best not to prune till the end of the second year. Beech, Holly, Laurel, Yew, Box, Hornbeam, and Birch, however (the plants that do not stand trimming at time of planting), always do best if allowed to stand two years before being pruned. And a well-kept hedge only needs hoeing, not digging, to keep it clean and free from weeds.

A young Thorn hedge planted in November or February will during the following summer probably make shoots averaging 12 inches, while Beech plants may only have grown from 2 to 3 inches. If the Thorn plants have not been trimmed, they may perhaps be no larger than the Beech; but if the Beech have been trimmed in the same way as the Thorns, about half of them will probably be dead.

Regular cleaning and pruning are the two main points in tending a hedge. For the first two years after planting it should be kept free from weeds by being carefully hoed twice a-year, in June and August. Unless the growth of weeds be checked, they interfere with the lowest branches and make the hedge thin at the base. By first of all bare-fallowing the ground and cleaning it of grass and weeds, the danger of the base being choked is diminished. This is the only way to ensure a good thick fence. The ground should be kept clear of weeds for 1 ft. beyond the **drip** on each side, to secure a free current of air, without which a hedge is sure to become thin and weak below. When once the ground has been properly weeded for some years, the annual cleaning may be done at a low cost. The cost of cleaning, pruning, and maintaining hedges on well-managed estates should not exceed about 1½d. a-perch (6d. a-chain), or about £2 a-mile per annum. But if fences are neglected, and are not cleaned for several years (as is often the case), the cleaning may cost a very great deal more; and unless they are kept clean, hedges are of little use as fences.

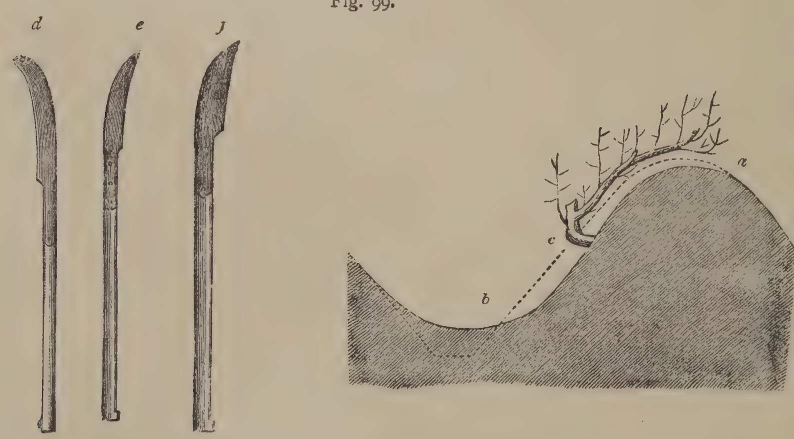
When the hedge is to form a fence against cattle, it is necessary, besides keeping it clean, to prune it annually to the standard form best suited for the object in view. Unless hedge-fences are trimmed annually, the hedge soon gets bare below and straggling at the top; it becomes loose and open, and is then no longer a cattle-fence.

At the end of the second year the hedge may be pruned for the first time by being cut back to about 9 inches from the surface, the sides being at the same time cut rather close. The best tool to use for this is the **switching-bill**, having a curved blade 9 in. long and 1½ in. broad, a helve 27 in. long, and a total weight of about 2½ lb. (fig. 99, *d*, *e*). It is used with a rapid upward, slightly slanting, stroke. Shears can also be used, but they are apt to make a rough wound, generally attended with the loss of a bud or two under the wound, whereas the switching-bill makes a clean cut without bad after-effects. A **well-switched** hedge is therefore closer and firmer than one clipped with shears. In pruning a hedge for the second time at three years old, it should be cut back to about 15 inches high and made even on the top, while at the side only about 2 inches of this last year's growth should be left. Pruning is continued thus each year until the full height of the required fence has been attained. Each successive cutting leaves it from 4 to 6 inches higher, and at least 2 inches broader on each side, than it was when pruned in the previous year; but after it is $4\frac{1}{2}$ ft. high it should be cut back as nearly to that height as possible.

However well kept, a hedge is apt in course of time to assume a thin, open, overgrown appearance. There is no better way of remedying this state than what is termed **ribbing** or **breasting-over**; and this consists in stripping the hedge of its side branches and encouraging it to make new wood. But in doing this caution must be used, otherwise the hedge may die down to the surface, and have to be coppiced to spring afresh from the stool.

If the situation be sheltered and not too elevated, the ribbing may be done whenever convenient between November and end of March. The tool used is the **ribbing-bill** or **breasting-knife** (fig. 99 *f*). It is stronger, heavier, and less curved than the switching-bill. It has a blade 7 in. long and $2\frac{1}{2}$ in. broad, a helve $2\frac{1}{2}$ ft. in length, and weighs in all about 6 lb. The hedger uses this bill with an *upward* stroke, cutting off all the lateral branches to within about 4 inches of the main stem upon each side, and reducing the hedge to about 3 ft. in height. To have greater freedom, the hedger may first use the light switching-bill to trim away all the smaller shoots and get rid of the prickles on them. The ribbing should, if pos-

Fig. 99.



sible, be done when the field is under an arable crop, a year or two before stock will be grazed, else sheep and cattle will be sure to damage the hedge by eating the young shoots and by rubbing against it. Where the situation is high or exposed, the work should not be done before March or April, when the coldest season is at an end. If done before then, the hedge may die down to the ground.

In the breasting of bank-and-ditch hedges the work is, of course, carried out on the same principle as in common live-hedges, though it may vary in detail according to special circumstances, as shown in Fig. 99, where *a* is the top of the hedge-bank, *b* the base of the ditch, and *c* the main stem of the Thorn, while the dotted line represents the original contour of the ditch and bank.

Where Hawthorn hedges have been badly managed for some years in succession, many of the plants become stunted, gaps occur here and there from plants dying, and the more healthy of the Thorns become tall and spreading. This may be caused either by want of thorough drainage, by neglect of weeding, or by the soil not being suited to the plants; or it may also be due to neglect of pruning and allowing them to spread, for Hawthorn is a light-demanding species of shrub-like tree. To remedy such defects, the plants should be coppiced about 6 inches above the ground, the cuts being made upwards and as sharp and clean as possible.

In coppicing old hedges the twigs are first removed with the switching-bill, and then a light **hedger's axe** is used (about 3 ft. long and 3 lb. in weight). The cutting strokes are made upwards, and the split portion is severed by a downward blow of the axe. When this has been completed and the brushwood removed, the ground should be cleaned and dug to about 2 ft. on each side of the hedge (to aerate the soil), and gaps among the stumps should be filled with new plants. In filling blanks in Hawthorn hedges Beech or Hornbeam have often to be used, because, owing to Hawthorn being **light-demanding**, new plants seldom succeed where overshadowed.

Work of the above kind may be done at any time during open weather from autumn to early spring. But in the case of Hawthorn hedges it will only answer well if the Thorns are still comparatively healthy. Old, straggling, much-neglected hedges never entirely recover so as to form a good stout fence. In such cases it is often best to dig them up and plant a new hedge. If the new line of fence is to occupy the same ground as the old, the soil should be trenched to a breadth of 5 ft. and a depth of 2 ft., and the young hedge planted in it in the usual way. But when the soil has become exhausted and deteriorated, no other method is more likely to secure good results than to bring good soil from an adjoining field and fill up the trench with this. Much good may, however, be done by layering or plashing shoots to form roots for themselves, as elsewhere described (see p. 385).

Stunted unhealthy bank-and-ditch hedges can often be improved by laying drain-pipes in the ditch and filling it up, and this also gives back the width of the ditch for agricultural use.

The best time for pruning **Evergreen Hedges** is generally the month of April, but this may vary with the local climate, the nature of the season, and the kind of hedge-plant.

Hedgerow Timber[1] was in the olden times a national necessity, as is clear from the historical details already given in chap. i. of the *Introduction*, for it was one of the best ways of growing curved and crooked Oak for ship-building. But no such urgent necessity now exists, and hedgerow trees are still maintained more for beauty than for timber. Hedgerow trees—and more especially those which, like Ash and Elm, throw out long spreading superficial roots—rob the agricultural land of no small portion of its soluble nutrient salts, thus diminishing its productivity. And at the same time the physical fact is indisputable that all portions of the field-crops lying to the west, north, and east of the hedgerow trees do not get the fullest possible

[1] An article on *Hedgerow and Field Timber* will be found in the *Trans. Scot. Arbor. Socy.*, vol. xi., part iii., 1887, pp. 550-561.

supplies of sunlight and warmth in the morning, noonday, and afternoon No matter how fertile any land may be, it is only under the light and warmth of sunshine that the soil can be rendered productive; and hedgerow trees interfere very directly and decidedly with such productivity by reason of the shade they cast on the crops. If any one doubt this fact, let him make unprejudiced observations when the grain ripens next summer. Let him also weigh a few ears of grain taken from near the north side of the trees, and compare the result with the weight of the grain from another part of the same field that has grown in full enjoyment of the sun's life-giving light and warmth. The matter of hedgerow trees is of very real agricultural importance to the landowners and farmers of Britain. In former days in Oxfordshire, for example, landowners used to stipulate for at least a certain number of trees being maintained; but now tenants stipulate that at most only a smaller number shall be retained. Nor is hedgerow timber equal in general quality to that grown in woodlands.

The rural beauty of England would be ruined if the hedgerow trees were all cut down; any such stringent (and logical) application of economic principles would be disastrous to the country. But agriculture would certainly gain if all such trees were felled and the soil utilised to its fullest capacity, and if protective woodlands were formed on hillsides and poor land not remunerative under arable or pastural occupation.[1]

The advantage is claimed for hedgerow trees that they produce shelter for stock and crops. When one considers that the trees are in leaf only from April or May till September or October, the specious plausibility of this

[1] The purely agricultural view of the matter is as follows:—

"**Trees and Hedges.**—If cattle are to be grazed on the fields, Beeches or forest-trees should never be planted in the line of Thorns, for it is impossible, even with the greatest care, to rear Thorn plants, to become a good and beautiful fence, under their drip. Thorns are impatient of being overshadowed by taller trees; and trees planted on the top of a mound, betwixt double hedges, not only rob both of moisture at the roots, but pour their drip directly upon the branches of the Thorns.

"'To plant trees in the line of a hedge,' says Lord Kames in his *Gentleman Farmer*, p. 283, 'or within a few feet of it, ought to be absolutely prohibited as a pernicious practice. It is amazing that people should fall into this error when they ought to know that there never was a good Thorn hedge with trees in it. And how should it be otherwise? When suffered to grow in the midst of a Thorn hedge, the tree spreads its roots everywhere, and robs the Thorns of their nourishment. Nor is this all: the tree, overshadowing the Thorns, keeps the sun and air from them. At the same time, no tree takes worse with being overshadowed than a Thorn.'

"Hedgerow trees are strongly recommended by the old writers on agriculture as being the best means of growing timber for the navy, and giving shelter to fields; and a writer on timber (Matthew, *On Naval Timber*, p. 359) seems to favour the plan of planting the Oak in hedgerows, as if that tree could not be sufficiently gnarled for naval purposes, and rendered thick in the bark for tan, in other exposed situations than in Thorn hedges" (Macdonald's edition of Stephens's *Book of the Farm*, 1893, Div. V., p. 219).

I know a grazing farm in the south of England where the hedgerows are filled with timber trees, mostly Elm. In 1901 the tenant told me he could well afford to give 5s. an acre more for rent yearly if the timber were cleared. At twenty-five years' purchase this means an immediate increase of about £6, 5s. an acre to the *capital value* of the land, besides the yearly increase in rent. Under the excessive amount of timber standing the hedges were broken and in gaps, no longer forming *fences*.

argument becomes apparent. Such trees give little or no shelter from cold biting winds; and as far as shelter from the hot summer sun is concerned, an Oak-tree here and there in grass lands—near the centre of the field, not in the hedge—is far more effective than hedgerow trees, which only spoil the fence by overshadowing it. Where shelter from wind is required for fields or stock, broad thick shelter-belts should be planted for this express purpose. The benefits obtainable thereby are undoubted (see *Introduction*, p. 101), but they are never attainable through hedgerow timber alone.

Hedgerow trees, being freely exposed, naturally have a strong tendency towards ramification. To a certain extent this can be checked by pruning which also helps to lessen the shade cast on the hedge and on the field-crop. But pruning only mitigates the evil, and the disadvantages of over-shadowing must exist wherever trees stand in hedgerows; whilst it also, of course, diminishes the shelter claimed to be one of the great advantages of hedgerow trees.

Everything being considered, Oak is certainly the best tree for hedgerows and fields—except where a tree happens to overhang a pool in a soil containing iron; because when the leaves fall in autumn, the tannic acid they contain turns the water inky, and cattle will not drink at the pool till it becomes re-filled with fresh water after the rains of the following spring. Next in general suitability after Oak come English Elm, Sycamore, Maple, Birch, Sweet-Chestnut, Black Italian Poplar, and, in some situations, the Cracking Willow. These are all trees of more or less upright habit, and which stand pruning. The Ash is very common as a hedgerow tree, although it is really one of the most unsuitable. When thus freely exposed to light and air, it is apt to branch off into large limbs, while the roots spread far and impoverish the land,—a fault of the Elm also.

The Beech is entirely out of place in a hedgerow because of the heavy shade it casts, under which neither hedge, nor grass, nor grain can thrive; nor can these prejudicial effects be remedied by pruning.

The various species of Pine, Spruce, and Fir, though all trees of upright habit, are not adapted for hedgerows, as they always thrive best when grown in masses; while even the Larch has rather a poor appearance as a hedgerow tree.

When available, it is best to select some sapling or strong sucker from the hedge as a standard, otherwise young trees must be planted. Plants intended for hedgerows should be frequently transplanted in the nursery to stimulate the growth of fibrous roots. The transplants should be pruned to a pyramidal shape, with one leader only; and the young trees should be 6 to 8 ft. high when planted, because they do not establish themselves easily if larger, and are then more apt to ramify than to grow in height. Unless regularly pruned to a height of 10 to 15 ft., the hedge below them suffers from overshadowing. To reduce the amount of shade, their branches should be shortened every two or three years; and even when the trees have grown to full size, the branches should not be allowed to extend more than 8 or 10 ft. over each side of the hedge.

Trees in Towns.—As plants give out oxygen and assimilate carbon in decomposing the carbonic acid of the atmosphere under the action of sunlight, trees must have a hygienic as well as an æsthetic effect in the impure atmosphere of large towns.

During the hours of darkness an opposite action takes place, and oxygen is absorbed from the air; but as, during most of the time the trees are in foliage, the hours of light greatly outnumber those of darkness (especially during the warm summer months, when assimilation is most active), the effect of trees in crowded towns must be to purify the vitiated atmosphere.

All kinds of trees are not, however, equally endowed in this respect; nor are they all alike capable of thriving in the impure atmosphere of large populous centres. In comparison with trees having broad flat leaves, coniferous or needle-bearing trees—whether with short leaves as in Spruce and other true Firs, or long needles as in Pines—are much less suited by nature for resisting the choking effect of the soot-laden atmosphere and the chemical action of the sulphurous acid with which the air is tainted (see also vol. ii., Part IV., chap. vi.)

While the leaves of conifers are *per se* more liable to be poisoned by sulphurous acid than those of broad-leaved species (Oak, Plane, Elm, &c.), the persistence of the foliage for several years increases their liability to disease. Again, during the winter months the foliage of evergreen conifers is exposed to the most poisonous fogs, from which deciduous trees escape. While about 4 volumes in 10,000 represent the normal amount of carbonic acid in large towns, it sometimes rises to as many as 14 volumes in a London fog. And, what is far more important as regards plant-life, along with this abnormal excess of carbonic acid a simultaneous increase also takes place in the percentage of the sulphurous acid evolved in the burning of coals, because, of all the impurities in the air of large cities, sulphurous acid is by far the most injurious to tree foliage. Owing to our more extensive use of mineral coal, the atmosphere of our large towns contains more sulphurous acid than that of Continental cities. When this is washed down into the soil by rainfall it is rapidly transformed into sulphuric acid, and, coming in contact with various alkalies, soon enters into combinations which make it innocuous to the root-systems of the trees. But the sulphurous acid is absorbed both by the upper and the under surfaces of leaves (the under surface being the more easily affected owing to the larger number of air-holes scattered over it), and is conducted from there to the tissue of the young shoots and twigs. The first action of the acid is to interfere with the normal rate of transpiration of moisture through the foliage, thus disturbing the due balance between absorption through the rootlets, diffusion throughout the stem and branches, and transpiration through the leaves or needles.

The power of doing damage is, however, greatly intensified when rain falls or dew is precipitated on the foliage, because the moisture converts the sulphurous acid into sulphuric acid ($SO_2 + H_2O = H_2SO_4$), which is very injurious in its action.[1] Hence, in comparison with deciduous trees, conifers are exposed to greater and much more prolonged deteriorating influences predisposing them to a diseased condition; while at the same time they are by nature less fitted for throwing off the effects of impaired vitality, owing to the smaller reserves of starchy and nitrogenous nutrients they store up as compared with broad-leaved trees. It has been asserted that the chemical action of the sulphurous and sulphuric acids is really of less importance than this clogging of the pores with fine particles of carbon, and that

[1] According to a paper read by Dr Bailey before the British Association in 1892, freshly fallen rain in Manchester was found to contain as much as 70 parts per million of sulphuric acid, while rime formed on the leaves during frost proved by far the most impure form of moisture, some samples collected showing nearly 400 parts per million of sulphuric acid. He also found that the increase in the amount of sulphurous acid in foggy weather was accompanied by at least as large an increase in the amount of organic impurities in the air, whereby the pores of the leaves were apt to get clogged with soot, &c.

rough-leaved trees like Horse-Chestnut and Elm are therefore less suitable for towns than smooth-leaved kinds such as Lime, Ash, Plane, and Poplars, whose foliage gets washed cleaner during rainfall. If disease mainly depended on this clogging of the pores with organic matter, however, then conifers would suffer less than other trees, as their needles are smooth and easily cleansed by heavy rain; and against this we have the well-known fact that conifers do *not* thrive in large smoky towns. The specific action of the sulphuric acid is to produce a yellowing of the needles near their tips, which gradually turns into a dark brown, and ultimately occasions the premature shedding of the older foliage one, or two, or more years before it otherwise would have become defoliated if the trees were growing in a pure atmosphere. In broad-leaved trees similar effects may be seen in yellow, brown, or red patches on the leaves, and more particularly round the edges, though the specific action of the poison varies according to each kind of tree (see Figs. in vol. ii., Part IV., chap. vi.)

Even should the spring flush of leaves in broad-leaved trees get clogged up and become defoliated during the second half of summer, the midsummer flush, appearing at the hottest time of the year, when vegetation is most energetic, carries on the work till all the leaves are shed, perhaps somewhat immaturely, in autumn. But in conifers the foliage remains persistent, except on the deciduous Larch; and the late days of autumn, the wintry months, and the bleak days of early spring, are more laden with poison than is the case at any time of the year when the broad-leaved deciduous species are in foliage.

Experience and experiments have both shown that, among conifers, the Silver Fir suffers most from atmospheric impurities, then the Spruce, the Scots Pine, and least of all the deciduous Larch. That is to say, the longer the foliage persists and the denser it is, the more liable are the trees to injury, and the less likely are they to thrive or to maintain themselves in a tolerably healthy condition.

Among broad-leaved species, however, seeing that they throw off part of their foliage in early autumn, and the remainder long before the windy weather of late autumn has given place to short wintry days, other factors practically determine their suitability or non-suitability for the adornment of densely populated and smoky centres like London, Birmingham, or Manchester. The two factors of greatest importance are the susceptibility of the leaves of each individual kind of tree, and its inherent reproductive and recuperative power; for the kinds of trees most likely to maintain a successful struggle against predisposition to disease are those endowed with a strong recuperative power combined with a small degree of sensitiveness in the foliage. It is impossible to make any hard-and-fast classification of trees as regards their suitability or non-suitability for cultivation in towns; but it may at least be said that Beech suffers most from gaseous atmospheric impurities, and Oak and Oriental Plane least, and that Birch, Lime, Alder, Ash, Maple, Sycamore, Aspen, Poplar, Horse-Chestnut, Elm, Acacia or Locust-tree (*Robinia*), the Japanese maidenhair-tree (*Gingko*), the Indian Bean (*Catalpa*), and the Tree of the Gods (*Ailanthus*) occupy intermediate positions between these extremes. Of these, only the Plane, Maple, Sycamore, Lime, Horse-Chestnut, and Elm are really suitable as avenue trees, while all the others find their proper places in gardens, open spaces, and parks, rather than in formal rows along streets or in the formation of avenues lining embankments.

So far as actual hardiness against the injurious effects of atmospheric impurities is alone concerned, no trees are better able to resist them than Oak and the London Plane. Other things being equal, these deserve special attention when planting operations are carried out in towns or their immediate vicinity. But as Oak is comparatively slow in growth, this is of course a drawback to its use on any large scale when speedy results are desired, so that the hardy and beautiful Plane must be regarded as the chief tree for street and town ornamentation.

Other æsthetic considerations beyond the healthiness of the trees themselves, however, play an important part as regards the adornment of streets by the planting out of trees; and in many cases there are what one might almost call national differences of taste exhibited in the matter.

Throughout the whole of Central Europe—in France, Central and Southern Germany, Western Austria, and Northern Italy—the Plane, and then in much smaller numbers the Horse-Chestnut and its prettier half-sisters, the red- and the yellow-flowering Buckeye (*Pavia*), are the trees generally favoured by municipal authorities for the adornment of towns. And this, too, despite the fact that in very dry seasons the Horse-Chestnut sheds its leaves long before they are nipped by early frosts in autumn. Such early defoliation does not necessarily indicate any diseased condition of the tree; nor does it mean that the foliage or flowers of the following spring will be less abundant than hitherto.

In the larger towns of Northern Europe Lime, Elm, Maple, Sycamore, and Plane are the trees most frequently planted, although Horse-Chestnut is still favoured on account of the beauty of its flowers and foliage in early spring. In Rotterdam, for example, a well-planted town, most of the street trees are small-leaved Elms, while Sycamore and Horse-Chestnut come next in favour, but in comparatively small number. And there can be no doubt that, taken all in all, Elm is certainly one of the species best adapted, along with Plane, Horse-Chestnut, Maple, and Sycamore, for the beautification of populous centres, even although its limbs are apt to fall without showing premonitory symptoms of disease or extreme tension. It is only by careful lopping of the Elms in the London parks that accidents there are almost unknown. Where spring beauty is particularly desired, the Horse-Chestnut is likely to find greatest favour; and where more weight is laid on securing pleasant autumn tints in the foliage, the Maples deserve special attention. But, for purposes of general adornment throughout the leafy season from April till October, Plane and Elm will certainly hold their own against any other trees.

In the London parks experience has shown that next to the Plane, the Elm, Sycamore, and the Robinia usually thrive best on the whole, while the Canadian Poplar does very well for about twenty years, after which its foliage gets poor and ragged, so that it is only useful as a temporary screen. Different species of Lime and of Ash also do well, while the thick leathery-leaved Japanese Maidenhair-tree (*Gingko biloba*), the Indian Bean (*Catalpa bignonioides*), and the Tulip-tree (*Liriodendron tulipifera*) are all three good ornamental trees which ought to be planted in larger numbers in the future than they have been in the past.

A good plan is adopted in Paris of having large open gratings 6 ft. in diameter, which can be lifted from time to time. Though not necessary for providing soil-moisture, this helps to aerate the soil, and the benefit will be all the greater if the earth is loosened by a pick.

END OF THE FIRST VOLUME.

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