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THE
ELEMENTS OF BRITISH FORESTRY

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A HANDBOOK FOR FOREST APPRENTICES
AND STUDENTS OF FORESTRY

BY

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P R E F A C E.

THIS contribution to the literature of Forestry, and towards technical education as outlined in the "Afforestation Policy" of the Development Commission, deals specially with British conditions.

It is intended not only for Forest Apprentices, both during their practical work in the woods and when they are receiving theoretical instruction either on private estates or at a School for Forest Apprentices, but also for Students of Forestry at Agricultural Colleges and Universities.

During its passage through the press the Scottish Forestry Committee has been appointed, to make recommendations regarding (1) the acquisition of a Forest Demonstration Area in Scotland, (2) the uses to which such an area may be put (including the establishment of a Forest School, as already provisionally approved in advance by the Development Commissioners), and (3) any further steps which it is desirable should be taken for promoting Sylviculture in Scotland. The importance of this last reference may be understood from the fact of the Royal Commission on Afforestation having (in 1909) reported that, of a total plantable area aggregating 9,000,000

acres throughout the United Kingdom, no less than two-thirds, on which 6,000,000 acres of timber-plantations can be formed, are to be found in Scotland.

Our present position with regard to Forestry, and to imports of wood, timber, wood-pulp, &c., is indicated on pages 23 to 25, and need not be recapitulated in this preface.

J. NISBET.

July 19, 1911.

CONTENTS.

CHAP.	PAGE
PART I.—SYLVICULTURE.	
I. OUTLINES OF THE HISTORY AND THE SCIENTIFIC FOUNDATIONS OF BRITISH FORESTRY ; OUR TIMBER-TREES, AND THEIR SYLVICULTURAL CHARACTERISTICS ; AND THE DIFFERENT FORMS OF WOODLAND CROPS	3
II. THE FORMATION, TENDING, AND RENEWAL OF WOODLAND CROPS	47
PART II.—THE MANAGEMENT OF WOODLANDS.	
I. THE MEASUREMENT OF LOGS, STANDING TREES, AND WHOLE CROPS OF TIMBER, AND OF THEIR INCREMENT OR RATE OF GROWTH	89
II. THE THEORETICAL PRINCIPLES OF WOODLAND MANAGEMENT	104
III. THE MAKING OF A WORKING-PLAN	130
IV. THE VALUATION OF TIMBER-CROPS AND OF WOODLANDS .	139
PART III.—THE PROTECTION OF WOODLANDS.	
I. PROTECTION AGAINST HUMAN ACTS, FARM-STOCK, GAME, RODENTS, AND BIRDS	159
II. PROTECTION AGAINST INJURIOUS INSECTS	181
III. PROTECTION AGAINST WEEDS, EPIPHYTES, AND FUNGUS DISEASES	233
IV. PROTECTION AGAINST DAMAGE FROM INORGANIC CAUSES	253

PART IV.—THE UTILISATION OF WOODLAND
PRODUCE.

I. TIMBER : ITS STRUCTURE, IDENTIFICATION, COMPOSITION, TECHNICAL PROPERTIES, PRACTICAL USES, AND MARKET VALUE	263
II. THE HARVESTING OF WOODLAND PRODUCE, AND ITS PRE- PARATION AND SALE	280
III. TIMBER-TRANSPORT BY LAND AND WATER	291
IV. THE SEASONING AND PRESERVATION OF TIMBER	299
V. WOODLAND INDUSTRIES : ESTATE SAWMILLS, PREPARA- TION OF WOOD-PULP AND CELLULOSE, CHARCOAL- MAKING, RESIN-TAPPING, ETC.	310
<hr/>	
INDEX	331

ILLUSTRATIONS.

FIG.	PAGE
1. Mound-planting	51
2. Pruning-shears	55
3. Cross-section of a drill-board to make drills 7 in. apart .	57
4. Cross-section of a seed-distributor	58
5. The Sowing-horn	58
6. Acorn-dibbler	58
7. Notched Seedling-pricker	59
8. British method of notching	66
9. Cramping of roots after notching	66
10. The iron-shod Dibble for vertical notching	67
11. S-conical Spade	68
12. Pitting with Cylindrical or Semicircular Spades, and plants with balls of earth	69
13. Method of Mound-planting	70
14. Ordinary Mound-planting with naked plants	70
15. Combination of Pitting and Mound-planting with naked plants	70
16. Combination of Pitting and Mound-planting with ball plants	70
17. Combination of Notching and Mound-planting with naked plants	70
18. Planting in lines, each planter, 2, 3, 4, taking his line from the foreman, 1	71
19. The Scribe	77
20. Good and bad methods of cutting coppice	81

21. The Measuring-Board	92
22. The Mirror-Hypsometer	93
23. The Telescope-Hypsometer	94
24. Best form of Calliper	95
25. Pressler's Borer	100
26. Actual rate of growth of Pinewoods on medium land	110
27. (a) Regular Series of Annual Falls ; (b) Part of a Regular Course of Annual Falls	111
28, 29. Subdivision of Woodlands into Compartments	117, 118
30. A Scots Pine Conifer working-circle	122
31. Method of Severance	123
32. A 7-foot Straining-post at end of a six-wired fence, 4 feet high	167
33. Cheap form of Fence	169
34. Damage caused by Game and Rodents	170
35. Clear-felling of a Spruce-wood, mixed with Scots Pine and Beech (Saxony, 1900)	188
36. A sample-plot of Scots Pine ringed with bands of patent tar to ascertain if the Nun-moth (<i>Liparis monacha</i>) is present (Saxony, 1900)	189
37. Spud and smoothing-stick (about $\frac{1}{5}$ th real size)	191
38. Elm-bark Beetle, magnified five times	196
39. <i>Hylesinus piniperda</i> , magnified seven times	197
40. Bark showing main and larval galleries and 2 air-holes— natural size. The ♂ keeps near the entrance-hole, while the ♀ bores the gallery	197
41. Shoot of Scots Pine, showing entrance-hole, and (where slice removed) boring of a beetle, $\frac{2}{3}$ natural size	197
42. Portion of young Ash-trunk with borings of <i>H. fraxini</i> , $\frac{3}{4}$ nat. size	199
43. The large Pine-weevil (<i>Hylobius abietis</i>)	202
44. Young Spruce gnawed by the large Pine-weevil (<i>Hylobius abietis</i>), natural size	202
45. The small Pine-weevil (<i>Pissodes notatus</i>)	204
46. Young Pine-stem barked to show the pupal-chambers and exit-holes of <i>Pissodes notatus</i> (half natural size)	204
47. The Common Cockchafer (<i>Melolontha vulgaris</i>)	206
48. Large Poplar Longicorn	208
49. Wire-worms	210
50. Winter Moth (natural size)	214

51. Part of Pine branch, showing damage done by caterpillars of the Pine Span-worm. Eggs can be seen here and there on the leaves	215
52. Oak Leaf-roller Moth—natural size	216
53. The Larch Mining-Moth (moth, larval covering, caterpillar, pupa—all magnified three times)	218
54. Goat-Moth—natural size	220
55. Pine Sawfly. Caterpillars at work; on right a cocoon (natural size). Damaged twig of Scots Pine	222
56. Cone-like gall of Spruce Aphis	226
57. The Larch Aphis sucking sap from the leaves, which get bent	226
58. Larch Canker	240
59. Young Beech stem cankered by <i>Nectria ditissima</i> . Young Spruce damaged by <i>Nectria curcubitula</i>	242
60. Damage to crowns of young Pine by <i>Cæoma pinitorquum</i> , the abnormal bends being caused by the fungus	244
61. Damage caused to Scots Pine by <i>Melampsora pinitorqua</i> in its <i>cæoma</i> -form, <i>Cæoma pinitorquum</i>	244
62. Willow Rust on Osier	245
63. Pine-shoot with sporophores of <i>Peridermium pini</i>	246
64. Twig of Spruce attacked by <i>Chrysomyxa abietis</i>	247
65. Leaves infected by <i>Chrysomyxa abietis</i>	247
66. Rot in Pine caused by <i>Trametes pini</i>	248
67. Sporophore of <i>Fomes annosus</i> on Scots Pine root	249
68. Young Scots Pine killed by <i>Agaricus melleus</i>	250
69. (a) Part of a Scots Pine root killed by <i>Agaricus melleus</i> , and showing an external rhizomorph penetrating the root at a. (b) Flattened internal rhizomorph from between bark and dead wood	251
70. Teeth of Two-handed Saws	281
71. Felling with Axe alone	281
72. Felling with Axe and Saw	282
73. Universal Wedge	282
74. Throwing with Common Jack	283
75. The Chain-Lever or Wood-Demon	283
76. Method of mooring the Chain to posts	283
77. Stump-extraction by hook-and-pole leverage	284
78. Revolving Numbering-Hammer	286
79. Seed-kiln for extracting Scots Pine seeds from the cones	290
80. Forest Tramway	292

81. Turning-Point and Buffer on a Roadway Timber-Slide .	295
82. A Brake or Check on a Wooden Timber-Slide . .	296
83. A Flume or Water-Shoot	297
84. Brake on end-section of raft, dragging on bed of floating-stream	298
85. Saw Bench for Staves and Pit-wood	312
86. Long-saw Benches for long Logs	312
87. View of small temporary Sawmill	312
88. Teeth of Band-Saw	314
89. Teeth of Circular Saws	314
90. Teeth of Frame-Saw	314
91. Conversion on the quarter	316
92. Dome-shaped (Paraboloid) Charcoal-Kiln	325

PART I.

SYLVICULTURE

CHAP.

- I. OUTLINES OF THE HISTORY AND THE SCIENTIFIC FOUNDATIONS
OF BRITISH FORESTRY; OUR TIMBER-TREES, AND THEIR
SYLVICULTURAL CHARACTERISTICS; AND THE DIFFERENT
FORMS OF WOODLAND CROPS.
- II. THE FORMATION, TENDING, AND RENEWAL OF WOODLAND CROPS.

CHAPTER I.

OUTLINES OF THE HISTORY AND THE SCIENTIFIC FOUNDATIONS
OF BRITISH FORESTRY; OUR TIMBER-TREES, AND THEIR
SYLVICULTURAL CHARACTERISTICS; AND THE DIFFERENT
FORMS OF WOODLAND CROPS.

Sylviculture is that one of the four main branches of modern Forestry which deals with the formation, tending, and renewal of woodland crops, in order to grow timber in the manner most profitable to the landowner. In this branch one has first to consider the different kinds of trees and their special peculiarities and general characteristics, and the different methods in which they can be treated as woodland crops, before one can give detailed consideration to the various stages in their growth and development—(1) the sowing or planting of new woods, (2) the weeding and thinning needed in tending young woods and plantations and those of older age, and (3) the renewal of mature wood-crops, either by reproduction through stool-shoots and root-suckers, or by regeneration through seed shed naturally or sown artificially.

Our Woodland Trees.—The timber-crops which can be grown in the British Isles comprise, owing to our mild, equable, damp climate, a very large number of different kinds of trees for so comparatively small an area. The indigenous trees which can be profitably grown as timber-crops are very limited in number, and include Beech, Hornbeam, Alder, Ash, Oak, Scots Elm, Aspen, Birch, White Willow, and among conifers only the

Scots Pine,—not reckoning the minor indigenous trees and shrubs found casually in highwoods or grown in coppices and underwoods, such as Cherry, Rowan, Sallow, Field Maple, Hazel, &c. Many valuable trees now thoroughly naturalised were introduced by the Romans, including English Elm, Chestnut, Lime, Black Poplar, White Poplar, and Horse-Chestnut ; while subsequent introductions have been, in fifteenth century, Crack Willow, Sycamore, and Spruce ; in sixteenth century, the Maritime Pine ; in seventeenth century, Silver Fir, Norway Maple, and Robinia ; in eighteenth century, Larch, Weymouth and Corsican Pines, and American Black Poplar ; in nineteenth century, Austrian Pine, Nordmann's and Great Silver Firs, Douglas Fir, Menzies Spruce, Lawson's and Large-coned Cypresses, Red Cedar (*Thuja gigantea*), Japanese Larch ; and in twentieth century, the American Larch. Though the countries to which the above are indigenous exhibit marked differences in climate, yet these trees can all thrive here as woodland crops worked purely on commercial principles for the growing of marketable timber. For poor land the conifers are on the whole the most valuable, being less exacting and more accommodative as regards soil, and also usually attaining saleable size sooner than broad-leaved trees, and especially some of the hardwoods (*e.g.*, Oak). This means not only earlier returns, but also less capital (land, plus growing timber-crops) being locked up in an industry that even under the most favourable circumstances is tardy in giving any fair monetary returns.

From a botanical point of view the trees commonly grown as, or found among, timber-crops may be classified as follows :—

A. BROAD-LEAVED TREES, *all deciduous*—

(a) *Flowers bisexual or hermaphrodite* (both male and female organs in same flower).

I. *Fraxineæ* : (1) Ash (*Fraxinus excelsior*).

II. *Ulmaceæ* : (1) English or Small-leaved Elm (*Ulmus campestris*) ;
(2) Scots or Wych Elm (*Ulmus montana*).

III. *Aceraceæ*: (1) Sycamore or Scots Plane (*Acer pseudo-platanus*); (2) Norway Maple (*Acer platanoides*).

IV. *Tiliaceæ*: (1) Lime (*Tilia parvifolia* and *T. grandifolia*).

V. *Hippocastaneæ*: (1) Horse-Chestnut (*Æsculus hippocastanum*).

VI. *Pomaceæ*: (1) Rowan or Mountain-Ash (*Sorbus aucuparia*); (2) Wild Service-tree (*Sorbus torminalis*); (3) Whitebeam (*Sorbus aria*).

VII. *Amentaceæ* (having flowers in catkins)—

a. *Flowers unisexual, monœcious* (both male and female on same tree).

1. *Cupuliferæ* (having fruits attached to a cup-shaped involucre): (1) English or Pedunculate Oak (*Quercus pedunculata*); (2) Sessile or Durmast Oak (*Quercus sessiliflora*); (3) Beech (*Fagus sylvatica*); (4) Hornbeam (*Carpinus betulus*); (5) Sweet-Chestnut (*Castanea vulgaris*).

2. *Betulaceæ* or Birch tribe: (1) Birch (*Betula alba*); (2) Common Alder (*Alnus glutinosa*); (3) White Alder (*Alnus incana*).

b. *Flowers unisexual, diœcious* (male and female on different trees).

3. *Salicinææ* or Willow tribe: (1) White Willow (*Salix alba*); (2) Crack Willow (*Salix fragilis*); (3) Bedford Willow (*Salix Russelliana*, a hybrid of above); (4) Aspen (*Populus tremula*); (5) Black Poplar (*Populus nigra* and *P. canadensis*); White Poplar (*Populus alba*).

B. CONIFER TREES (*Coniferæ*), all evergreen except the Larch; and all with unisexual, monœcious flowers)—

I. *Abietinææ*, Pine and Fir tribe—

1. PINES (*Pinus*): (1) Scots Pine (*P. sylvestris*); (2) Austrian Pine (*P. austriaca*); (3) Corsican Pine (*P. laricio*); (4) Maritime Pine (*P. pinaster*); (5) Weymouth Pine (*P. strobus*).

2. SPRUCES (*Picea*): (1) Common or Norway Spruce (*P. excelsa*); (2) Menzies or Sitka Spruce (*P. sitchensis*).

3. SILVER FIRS (*Abies*): (1) Common Silver Fir (*A. pectinata*); (2) Nordmann's or Crimean Silver Fir (*A. Nordmanniana*); (3) Giant Silver Fir (*A. grandis*).

4. DOUGLAS FIR (*Pseudotsuga Douglasii*): (1) Pacific or Oregon variety (var. *pacificensis*); (2) Inland or Colorado variety (var. *coloradensis*).

5. LARCHES (*Larix*): (1) Common or European Larch (*L. europæa*); (2) Japanese Larch (*L. leptolepis*).

II. *Cupressinæ*, Cypress tribe—

1. CYPRESSES (*Cupressus*): (1) Monterey or Large-coned Cypress (*C. macrocarpa*); (2) Lawson's Cypress (*C. Lawsoniana*); (3) Nootka Cypress (*C. nootkaensis*).

2. *Arborvitæ* (*Thuja*): (1) Red Cedar or Giant Arborvitæ (*Th. gigantea*, syn. *Th. plicata*).

These trees may be identified from their (1) *Buds*, (2) *Leaves*, (3) *Flowers*, and (4) *Fruits* by means of the following analytical tables, which follow no natural system, but are purely artificial and merely intended to simplify identification by those who have not yet studied Forest Botany:—

I.—IDENTIFICATION OF COMMON BROAD-LEAVED TREES FROM THEIR BUDS.

A.—BUDS OPPOSITE, AND END-BUD MUCH LARGER THAN SIDE-BUDS.

I. *Only 1 or 2 bud-scales visible; bud scales black; twigs smooth, greyish-green* 1. ASH.

II. *Several bud-scales visible, arranged closely and compactly; twigs thick and stiff.*

1. Bud-scales brown and resinous; leaf-scar large and triangular, with vascular bundles well marked 2. HORSE-CHESTNUT.

2. Bud-scales yellowish-green, with dark-brown tips and margins; leaf-scar well marked 3. SYCAMORE.

3. Bud-scales pinkish or reddish-brown, sometimes greenish at base; leaf-scar narrow 4. NORWAY MAPLE.

B.—BUDS ALTERNATE, IN TWO LONGITUDINAL ROWS, ON OPPOSITE SIDES OF THE TWIG.

I. *Buds pointed, pale brown, and often about 3 or 4 times as long as broad; twigs slender and smooth.*

1. Buds circular in transverse section, jutting out from twig, and usually over $\frac{1}{2}$ an inch long 5. BEECH.

2. Buds slightly angular in transverse section, lying close to twig, and less than $\frac{1}{2}$ an inch long 6. HORNBEAM.

II. Buds roundish-oval, and about twice as long as broad.

1. *Only 1 or 2 bud-scales visible.*

- (1) Young twigs with longitudinal ridges or angles, straight, deep red, or reddish-green; buds slightly on one side, and not immediately above the distinct leaf-scar

7. SWEET-CHESTNUT.

- (2) Young twigs cylindrical; buds blood-red or orange-red, with 1 large and 1 small bud-scale to each bud . . . 8. LIME.

(a) Twigs smooth . . . SMALL-LEAVED LIME.

(b) Twigs slightly hairy . . . LARGE-LEAVED LIME.

2. *Several bud-scales visible; buds round and somewhat pointed; bud-scales dark-brown; young twigs more or less hairy, older twigs with fine rich brown fissures in bark . . . 9. ELM.*

(a) Twigs thin and very regular; buds small and numerous; leaf-scars small=ENGLISH ELM.

(b) Twigs thicker and less regular; buds and leaf-scars larger=SCOTS OR WYCH ELM.

Hazel twigs are very similar to those of Elm; but Hazel-buds are rounder and flattened on one side, and have pale brownish-green or reddish-green bud-scales.

C.—BUDS ARRANGED SPIRALLY ON THE TWIGS.

1. *Buds stalked, and apparently only 1 bud-scale visible, of a purple or bluish colour . . . 10. ALDER.*

II. Buds sessile, with apparently only 1 large bud-scale (though really 2 united) . . . 11. WILLOW.

(1) Buds hairy and very small; old twigs reddish-grey and dull=WHITE WILLOW.

(2) Buds smooth and almost black; twigs brown and glossy=CRACK OR REDWOOD WILLOW.

(3) Buds smooth, yellowish or reddish, short and plump=SAUGH OR GOAT WILLOW.

III. *Buds sessile, with several bud-scales visible.*

1. Bud-scales more or less brown in colour, and smooth, or hairy only at tips and margins.

(1) Buds dark reddish-brown and glossy, small, thin, and sharp-pointed, about thrice as long as broad, and often arranged almost alternately; twigs thin, elastic, and often warty (on dry ground), or downy (on wet ground) . . . 12. BIRCH.

(2) Several buds clustered at tips of long shoots . . . 13. OAK.

(a) Twigs greyish-brown, furrowed, and hairless ; buds standing out from shoot, yellow-brown or chestnut-brown, smooth, plump, and rounded at tips = PEDUNCULATE OAK.

(b) Twigs slightly hairy ; buds longer and more pointed than in Pedunculate Oak, and bud-scales tipped and edged with hairs = SESSILE OR DURMAST OAK.

(3) Buds oval, and dark-brown 14. CHERRY.

(4) Buds long, narrow-pointed, chestnut-brown, and resinous at tip ; twigs furrowed 15. POPLAR.

(a) Bud-tips lying close to shoot = ASPEN.

(b) Bud-tips straight or pointing outwards = BLACK POPLAR.

2. Bud-scales hairy all over, and buds plump and pointed ; young twigs covered with loose white cottony film ; older twigs smooth, yellowish-grey . . . 16. ABELE OR WHITE POPLAR.

3. Bud-scales dark-purple or black ; buds long, pointed, and somewhat downy near tip . . . 17. ROWAN OR MOUNTAIN-ASH.

4. Bud-scales yellowish ; buds long, pointed, and somewhat downy near tip 18. WHITEBEAM OR BEAM-TREE.

5. Bud-scales green, with narrow brown edges, buds thick and round at top 19. SERVICE-TREE.

IV. *Buds hidden below leaf-scar till near the time of opening in spring ;*

2 small sharp thorns just above each leaf-scar ; shoots angular

20. ROBINIA OR LOCUST-TREE.

II.—IDENTIFICATION OF COMMON BROAD-LEAVED TREES FROM THEIR LEAVES.

A.—LEAVES OPPOSITE.

1. Leaves unequally pinnate, with 7 to 11 ovate-lanceolate, toothed and almost sessile leaflets 1. ASH.

2. Leaves long-stalked, palmately (digitately) divided, with 5 or 7 almost sessile leaflets (usually 7) . . . 2. HORSE-CHESTNUT.

3. Leaves long-stalked, palmate, smooth, palmately veined and lobed, the 5 or 7 main veins converging to top of the long leaf-stalk (MAPLE) :—

(1) Leaves with 5 main veins, and 5 unequally toothed and pointed lobes 3. SYCAMORE OR SCOTS PLANE.

(2) Leaves with 5 or 7 main veins, and sharp-pointed lobes with a few coarse acute teeth 4. NORWAY MAPLE.

(These are both easily distinguishable from the 5-lobed leaves of the true Plane (*Platanus*), which are alternate, have the main nerve of the lowest lobe on each side joining that of the larger lobe above, and whose leaf-stalk is hollowed at the lower end, like a candle-extinguisher, to enclose and protect the new bud.)

B. — LEAVES ALTERNATE.

1. Leaves ovate, short-stalked ($\frac{1}{4}$ to $\frac{1}{2}$ inch long) and smooth :—

- (1) Leaves entire or obscurely toothed and short-pointed, with parallel veins wide apart from midrib to edge, silky and ciliated when young 5. BEECH.
- (2) Leaves doubly serrated and long-pointed, with close parallel veins from midrib to edge, and usually downy in vein-axils on lower side 6. HORNBEAM.

(Compare 8. *English Elm*; but *Hornbeam* can easily be distinguished from the *English Elm* in being smooth and not oblique at base, by the teeth and serratures being smaller, and by the parallel veins being closer to each other.)

2. Leaves on stalks $\frac{1}{2}$ to 1 inch long, oblong-lanceolate, smooth, very coarsely and regularly serrated, pointed tip, and parallel veins from the midrib to the teeth . . . 7. SWEET-CHESTNUT.
3. Leaves broadly ovate, almost sessile, doubly serrated, rough and very unequal or oblique at base (ELM) :—

- (1) Leaves usually small and short-pointed, doubly-toothed, but not very rough . . . 8. ENGLISH OR SMALL-LEAVED ELM.
- (2) Leaves large and broad, long-pointed, doubly-toothed and deeply serrate, usually rough above and somewhat downy below . . . 9. SCOTS OR WYCH ELM.

(A smooth-leaved variety, *U. glabra*, in the East of England is also called *Wych Elm*, and may possibly be indigenous.)

4. Leaves with stalks $\frac{3}{4}$ to 1 inch long, broadly heart-shaped or nearly round, but not equally divided by the midrib, and always pointed, toothed on edge, smooth above and more or less downy below, especially in the angles of the main veins, the four lowest of which usually converge on the leaf-stalk (LIME) :—

- (1) Leaves small, smooth, dark-green on upper surface and pale-green beneath, with rusty-brown hairs in the vein angles . . . 10. SMALL-LEAVED LIME.
- (2) Leaves large, pale-green on both sides, with whitish hairs in vein-angles . . . 11. LARGE-LEAVED LIME.

(The leaf of the HAZEL is often somewhat like that of the SMALL-LEAVED LIME, being alternate, broadly obovate or roundish and pointed; but it is easily distinguishable by its velvety upper surface, its short leaf-stalk (under $\frac{1}{2}$ inch), and its not having the four lowest main veins usually converging to the leaf-stalk.)

C.—LEAVES ARRANGED SPIRALLY ON THE TWIGS.

1. *Leaves more or less ovate or oblong, and sometimes lobed.*

(1) Leaves usually obovate or oblong, irregularly sinuate or almost pinnatifid, with lobes usually obtuse (OAK):—

(a) Leaves sessile or with short stalks, and broad, heart-shaped, crinkled base, smooth 12. PEDUNCULATE OAK.

(b) Leaves with stalk $\frac{1}{2}$ to 1 inch long, and wedge-shaped base, more or less downy in vein-angles beneath

13. SESSILE OR DURMAST OAK.

(2) Leaves ovate or oblong, wrinkled, smooth dark-green above, greyish downy below, pointed and generally twisted at tip

14. SAUGH OR GOAT WILLOW.

(3) Leaves broadly ovate or nearly round, doubly serrated, smooth or slightly downy in vein-angles beneath (ALDER):—

(a) Leaves dark-green and sticky, somewhat indented at top, with leaf-stalk 1 to $1\frac{1}{4}$ inch long (bark blackish-brown)

15. COMMON OR BLACK ALDER.

(b) Leaves long-pointed and paler in colour (bark light grey)

16. WHITE OR GREY ALDER.

(4) Leaves broadly ovate or obovate, and more or less downy when young (SERVICE-TREE):—

(a) Leaves loosely downy when young, but smooth when mature, broad and divided to near the middle into 5 or 7 broad and pointed lobes bordered with small teeth

17. WILD SERVICE-TREE.

(b) Leaves green and smooth above, but covered with soft white cottony down below (as also the young shoots), doubly serrated, sometimes undivided, sometimes more or less primately lobed, and lobes rounded at top (not pointed)

18. WHITEBEAM OR BEAM-TREE.

(5) Leaves ovate, or ovate-lanceolate, 2 to 4 inches long, toothed, smooth, with small free stipules often scarcely visible (CHERRY):—

(a) Leaves with a long stalk, sharply serrate, downy in vein-angles beneath, drooping, with long leaf-stalk bearing 2 prominent red glands 19. GEAN OR WILD CHERRY.

(b) Leaves smaller and with short leaf-stalk, smooth below, finely serrate, slightly heart-shaped at bud, and with less prominent glands 20. WILD BLACK OR BIRD CHERRY.

(6) Leaves usually broadly ovate, taper-pointed and toothed, but varying from triangular to rhomboidal or broadly heart-shaped, entire at base, doubly (and often trebly) serrated along the upper edges, smooth and shining on older twigs, and often with small glandular warty dots (especially on young leaves)

21. BIRCH.

(On dry soil the leaves and twigs are warty (COMMON BIRCH), but on wet soil they are pubescent (DOWNY BIRCH).)

2. *Leaves more or less triangular or rhomboidal, and with long stalks* (see also 21. BIRCH above).

(1) Leaves usually broadly triangular or rhomboidal or nearly round, on slender stalks (POPLAR):—

(a) Leaves very broadly ovate, mostly wavy-edged or coarsely toothed and sometimes lobed, more or less heart-shaped at base, and lower surface of leaf (as also the young shoots) covered with white cottony down (bark whitish)

22. ABELE OR WHITE POPLAR.

(b) Leaves smooth and green on both sides:—

(aa) Leaves often pale-green on lower surface, small and nearly round or rhomboidal (but large on stool-shoots and suckers, and shaped like those of the Abele) with bluntly notched or toothed edges, and long flattened leaf-stalk (hence leaf trembling with slightest breeze): (bark grey)

23. ASPEN OR TREMBLING POPLAR.

(bb) Leaves of same colour on both sides, with translucent edges, broadly rhomboidal or ovate-triangular, but never lobed, tapering at top, with lower angles rounded, and with small regular teeth (bark blackish) 24. BLACK POPLAR.

(The CANADIAN BLACK POPLAR has usually larger and darker green leaves than the COMMON BLACK POPLAR.)

3. *Leaves very much longer than broad, and more or less lanceolate, whole and unlobed, with short leaf-stalk* (WILLOW):—

(1) Leaves elliptic-lanceolate, pointed, serrate, grey or white with silky hairs on both sides (but especially on lower side), and the lowest serratures glandular

25. WHITE OR HUNTINGDON WILLOW.

(2) Leaves lanceolate, pointed, coarsely serrate, green and smooth, leaf-stalks glandular; twigs brittle at junction with stem

26. CRACK OR REDWOOD WILLOW.

4. *Leaves unequally pinnate* :—

- (1) Leaves with 11 to 19 leaflets, all narrow-oblong, toothed, and from 1 to 2 inches long, smooth or nearly so above, and more or less downy below . . . 27. ROWAN OR MOUNTAIN-ASH.
- (2) Leaves with 11 to 21 narrow, ovate, smooth, entire-edged, long-stalked leaflets . . . 28. ROBINIA OR LOCUST-TREE.

III. IDENTIFICATION OF COMMON BROAD-LEAVED TREES FROM THEIR FLOWERS.

A.—FLOWERS BISEXUAL OR HERMAPHRODITE, *i.e.*, CONTAINING BOTH THE MALE ORGANS (*stamens*) AND THE FEMALE (*pistil*):—

I. STAMENS FREE AND SEPARATE—

(a) FLOWERS INCOMPLETE, *i.e.*, without calyx or corolla, or with a floral envelope (*perianth*) in place of calyx or corolla, and the flowers appearing before the leaves.

1. Flowers each with 2 stamens and 1 pistil, clustered in short lateral racemes, without calyx or corolla (or sometimes monœcious, *i.e.*, with only male or only female organs, but both male and female flowers on same tree) . . . 1. ASH.

2. Flowers reddish, in dense lateral clusters, surrounded by brownish bracts forming a bell-shaped perianth with 4 to 6 short lobes or teeth, and as many stamens, and 2 pistils or 2 stigmas (ELM) :—

- (1) Flowers and perianth almost sessile, 4-cleft, brownish (March and April) . . . 2. ENGLISH OR SMALL-LEAVED ELM.
- (2) Flowers and perianth on longer stalks, loosely tufted, 5- or 6-cleft, reddish (April, May) 3. SCOTS OR WYCH ELM.

(b) FLOWERS COMPLETE, *i.e.*, with calyx, corolla, stamens, and pistil all present.

1. Flowers with bell-shaped 5-toothed calyx, and irregular 4- or 5-leaved corolla with white petals spotted with red near centre, and with 7 or 8 free stamens and 1 pistil with 2 stigmas ; flowers in stiff erect racemes 4. HORSE-CHESTNUT.

2. Flowers with 4- or 5-leaved corolla and calyx, 8 free stamens and 1 pistil with 2 stigmas (MAPLE) :—

- (1) Flowers green, in loose, oblong, hanging racemes, and appearing along with the leaves

5. SYCAMORE OR SCOTS PLANE.

- (2) Flowers yellowish-green, in upright corymbs, and appearing before the leaves 6. NORWAY MAPLE.

3. Flowers with 5-leaved calyx and corolla, numerous free stamens, and 1 pistil (CHERRY):—

(1) Flowers in umbels, long-stalked, large and white, appearing before the leaves . . . 7. WILD CHERRY OR GEAN.

(2) Flowers in loose and often drooping racemes, short-stalked, small and white, appearing with the leaves

8. WILD BLACK OR BIRD CHERRY.

4. Flowers in branching corymbs, white, with bell-shaped calyx, united with the ovary and 5-cleft at edge, corolla 5-leaved and attached, as also the numerous stamens, to the calyx, ovary 5-celled, with 2 pistils (SERVICE-TREES):—

(1) Flowers rather small, numerous 9. ROWAN OR MOUNTAIN-ASH.

(2) Flowers rather larger, but not nearly so numerous, usually 3 or 4 . . . 10. WHITEBEAM OR BEAM-TREE.

(3) Flowers fewer and larger than in (1), but more numerous and smaller than in (2) . . . 11. WILD SERVICE-TREE.

5. Flowers pale-yellow, in simple corymbs attached to a long lanceolate bract, with a 5-leaved calyx and 4- or 5-leaved corolla, and 20 or more stamens free or very shortly adhering in several clusters, and attached to the base of the calyx, below the ovary, and 1 pistil (LIME):—

(1) Corymbs with more than 3 flowers (5 to 13)

12. SMALL-LEAVED LIME.

(2) Corymbs usually with 2 or 3 flowers

13. LARGE-LEAVED LIME.

II. STAMENS NOT FREE, BUT UNITED INTO 2 BUNDLES; flowers papilionaceous, white, in loose, hanging racemes . 14. ROBINIA OR LOCUST-TREE.

B.—FLOWERS UNISEXUAL (*i.e.*, containing either only the male organs or only the female), ARRANGED IN CYLINDRICAL, OBLONG, OR ROUND SPIKES (called catkins), AND MONCECIOUS, *i.e.*, having both male and female flowers on the same individual tree.

I. *Catkins cylindrical or short, with closely packed scales; the male flowers with 2 stamens, and the females with naked ovules, either inserted within the catkin scales or solitary and quite exposed* (CONIFERE—see V., “Identification of Common Conifer Trees”).

II. *Catkins usually dense with closely packed scale-like bracts, rarely loose, or with minute deciduous scales, which subsequently (in the female flower) form an involucre for the fruit (Cupulifere).*

1. Male catkins in slender and interrupted pendulous racemes, without scales, but with a 5- to 9-cleft perianth and 5 to 9 stamens;

female catkins single or in small, sessile, short-stalked clusters, each with 1 ovary, 1 style, and 3 stigmas, enclosed in a many-scaled involucre (OAK) :—

- (1) Female catkins arranged in 3 or 4 on a long stalk (peduncle)

15. PEDUNCULATE OAK.

- (2) Female catkins solitary or clustered, and either closely sessile on the twig, or borne on a short peduncle about an inch long

16. DURMAST OR SESSILE OAK.

2. Male catkins with flowers having a 5- or 6-cleft perianth, and 10 to 15 stamens—

- (1) Male catkins round and pendulous; female catkins round, almost sessile, each flower having 1 ovary crowned by the six small teeth of the perianth, and 3 styles, and with a 4-valved hairy involucre enclosing two or three flowers sessile in centre of catkin 17. BEECH.

- (2) Male catkins very long and thin, with clusters of flowers arranged spirally; female catkins round, at base of the male catkins, and enclosed by an involucre of bristly scales, with a 5- to 8-styled ovary, crowned by a 5- to 8-toothed perianth

18. SWEET-CHESTNUT.

3. Male catkins, slender, lateral, cylindrical, and pendulous, with broad sessile scales, and flowers having 6 to 12 stamens attached to the base of the bract; female catkins terminal and loose, each flower with 1 two-celled ovary and 2 styles, and 2 flowers within each scale, each enclosed in a hairy unequally 3-lobed inner scale (involucre) 19. HORNBEAM.

III. Male catkins cylindrical, usually pendulous, with broad imbricated scales, and with anthers larger than their filaments (Betulaceæ).

1. Flowers appearing before the leaves. Each scale of the male catkin with 3 distinct flowers, each with 4 stamens; female catkins small and ovoid 20. ALDER.

2. Flowers appearing after the leaves. Male catkins with stalked scales, and 6 to 12 stamens within each scale, but not in distinct flowers; female catkins cylindrical 21. BIRCH.

C.—FLOWERS UNISEXUAL, ARRANGED IN ERECT OR PENDULOUS CYLINDRICAL OR OVAL SILKY-HAIRED CATKINS, BUT DICEIOUS, i.e., having the male flowers on one tree and the female flowers on another tree (Salicineæ) :—

- I. Catkins mostly erect and usually silky-haired, with entire catkin-scales; male flower with 2 (rarely 3 to 5) stamens on long filaments and 1 or 2 gland-like inner scales; female flower solitary*

within each scale, naked, with 1 ovary (usually long-stalked) and a forked style 22. WILLOW.*

- II. Catkins pendulous, with jagged catkin-scales; flowers having a perianth of inner united scales forming a small, flat, oblique cup; male flower with 8 to 30 stamens, with short, slender filaments and small anthers; female flower with 1 sessile ovary and a 4-forked style 23. POPLAR.*

(* The chief species of WILLOW and POPLAR can best be distinguished by their leaves.)

IV.—IDENTIFICATION OF COMMON BROAD-LEAVED TREES FROM THEIR FRUITS.

A.—FRUIT A 1-SEEDED INDEHISCENT NUT (NOT OPENING SPONTANEOUSLY, BUT FALLING OFF WITH THE RIPE SEED).

I. *Nuts solitary, or in clusters, or in loose spikes, and wholly or partially enclosed in a more or less cup-shaped involucre or husk (Cupuliferae).*

1. *Each nut having its own involucre.*

(1) Nuts (acorns) large and elliptical, and each surrounded at base with a short, hard, cup-shaped husk (OAK):—

(a) Acorns somewhat elongated and pointed, either clustered or spiked, above the middle of a flower-stalk (peduncle) 1 to 6 inches long 1. PEDUNCULATE OAK.

(b) Acorns somewhat short and less pointed, solitary or clustered, either closely sessile on the branch or borne on a short flower-stalk about 1 inch long

2. SESSILE OR DURMAST OAK.

(2) Fruiting catkin much elongated, the inner scales being enlarged into long, leafy, unequally 3-lobed bracts, each having attached to its base a small flat nut 3. HORNBEAM.

(The HAZEL has fruits usually clustered, each consisting of a large hard-shelled nut, nearly enclosed in a leafy husk unequally lobed and jagged.)

2. *Two or three nuts enclosed within one capsular involucre opening in 4 valves.*

(1) Nuts three-cornered and sharp-pointed, and 2 or 3 being enclosed within a hard cupule covered with coarse, short, soft prickles 4. BEECH.

(3) Nuts large and plano-convex, and 2 or three being enclosed within a thick cupule covered with long, thin, interwoven prickles 5. SWEET-CHESTNUT.

II. Nuts small and flat, in compact catkins (Betulaceæ).

- (1) Catkin-scales thin, and falling off along with the small seed having lateral wings (ripens July-September) . . . 6. BIRCH.
- (2) Catkin-scales hard, and remaining like a small oval cone after the unwinged seed is shed 7. ALDER.

B.—FRUIT AN INDEHISCENT SAMARA OR NUT WITH A WING AT ITS UPPER END.

- I. Samara dry, oblong, narrow, thin and flattened, about $1\frac{1}{2}$ inch long, light-brown, and arranged in racemes; each samara is two-celled, and each cell 1-seeded 8. ASH.
- II. Samara with 2 (sometimes 3 or 4) seeds, each with long flattened wing above and 1 or 2 seeds in each carpel (MAPLE):—
 - (1) Wings at an acute or right angle, and seeds roundish
9. SYCAMORE OR SCOTS PLANE.
 - (2) Wings between a right angle and horizontal, and seeds somewhat flattened 10. NORWAY MAPLE.
(The small FIELD MAPLE has its wings horizontal or forming an obtuse angle, and its seeds roundish.)
- III. Samara 1-seeded, with flat, thin, smooth, leaf-like membranous wing extending laterally as well as at top, and cleft at top end, ripening in May or June (ELM):—
 - (1) Fruit yellowish and above the middle of the seed-wing, oblong, so deeply cleft at top as almost to reach the seed-cavity, and with the hook-like tips overlapping each other considerably
11. ENGLISH OR SMALL-LEAVED ELM.
 - (2) Fruit green and about the middle of the seed-wing, roundish, less deeply cleft at top, and hook-like tips only slightly (if at all) overlapping each other . . . 12. SCOTS OR WYCH ELM.

C.—FRUIT A SMALL, DOWNY, YELLOWISH-GREEN, CORIACEOUS, ROUND 1- OR 2-SEEDED NUT, MORE OR LESS DISTINCTLY RIBBED, AND GROWING IN CORYMBES ATTACHED TO A MEMBRANEOUS BRACT (LIME):—

1. Corymbes with more than 3 small nuts faintly 5-ribbed
13. SMALL-LEAVED LIME.
2. Corymbes with large bract and not more than 3 nuts of large size, and prominently 5-ribbed . . . 14. LARGE-LEAVED LIME.

D.—FRUIT A DEHISCENT (SPONTANEOUSLY OPENING) SHORT OR THICK AND BROAD CAPSULE, SPLITTING LONGITUDINALLY INTO VALVES.

1. Capsule round and rough, with soft prickles, about $1\frac{1}{2}$ inch broad, and opening in 3 valves to shed 2 to 4 large, glossy brown seeds
15. HORSE-CHESTNUT.

F.—FRUIT A CATKIN FORMED OF DEHISCENT CAPSULES IN THE FORM OF LONG, NARROW PODS, OPENING LONGITUDINALLY INTO 2 VALVES, AND CONTAINING MINUTE SEEDS, EACH WITH A TUFT OF LONG COTTONY HAIRS (*Salicineæ*).

1. Scales of the catkin entire 16. WILLOW.*
2. Scales of the catkin toothed, lobed, or jagged. . . 17. POPLAR.*

(* The chief species of WILLOW and POPLAR can best be distinguished by their leaves.)

G.—FRUIT A 1-SEEDED DRUPE, EACH SEED BEING ENCLOSED IN A HARD STONE SURROUNDED BY A FLESHY COVERING (CHERRY):—

1. Fruits in umbels, long-stalked, large, red or black, smooth, round, and sweet, with a smooth stone 18. WILD CHERRY OR GEAN.
2. Fruits in racemes, short-stalked, small, black, smooth, nearly round, and bitter-sweet, with a rough stone 19. WILD BLACK OR BIRD CHERRY.

H.—FRUIT A BERRY (SORB) OR SMALL POME (miniature Apple), growing in corymbs at the ends of short leafy branches (SERVICE-TREES).

1. Berries numerous, small, round, and bright red 20. ROWAN OR MOUNTAIN-ASH.
2. Berries, usually 3 or 4, small, round or ovoid, brownish, with white spots 21. WILD SERVICE-TREE.
3. Berries large, round or ovoid, red or yellow, and covered with cottony down 22. WHITEBEAM OR BEAM-TREE.

I. FRUIT A LONG, MANY-SEEDED POD :— 23. ROBINIA OR LOCUST-TREE.

V.—IDENTIFICATION OF COMMON CONIFER TREES.

The *Coniferæ* grown in British woodlands are characterised by having linear or short and scale-like leaves; monœcious flowers in short or cylindrical catkins with closely-packed scales; male flowers with stamens inserted on the axis of the catkin within the scales, or the anther-cells sessile on the inside of the scales, which then form part of the stamens; female flowers with naked ovules and seeds (without ovary, style, or pericarp), either inserted within the catkin-scales or solitary and quite exposed. The Conifers grown as timber-crops in Britain belong only to the two following tribes, *Abietinæ* and *Cupressinæ*:—

I. Flowers monœcious, male catkins small and cylindrical, with 2 anther-cells to each scale; fruit a dry woody cone, with cone-bracts arranged spirally, 2 winged seeds within each scale (ABIETINÆ):—

- A.*—EVERGREEN TREES with leaves ranged spirally round the short shoots, and from second year onwards divided into 2, 3, or 5

needles encircled at base by a membranous sheath ; cone-scales narrow, and thickening near tip ; seed ripening in second year after flowering (true PINES) 1. PINE.

1. Each leaf divided into two needles—

- (1) Leaves about $1\frac{1}{2}$ to $2\frac{1}{2}$ inches long, cone small (SCOTS PINE).
- (2) Leaves from 3 to 4 inches long, stiff and prickly ; cone medium-sized (AUSTRIAN PINE).
- (3) Leaves from 4 to 5 inches long, cone large (CORSICAN PINE).
- (4) Leaves from 5 to 6 inches long, cones large and in clusters (MARITIME PINE).

2. Each leaf divided into 5 needles (WEYMOUTH PINE).

B.—CONE-SCALES BROAD, AND THIN AT TIP AND EDGES (true FIRS):—

1. EVERGREEN TREES with single, sessile, 2- or 4-sided, persistent leaves ranged spirally on twigs ; cones ripening in year of flowering :—

- (1) Defoliated twigs rough, with prominent leaf-scars ; seed-bracts short and not showing above the cone-scales ; cones pendulous, and scales persisting after seed is shed 2. SPRUCE.

(a) Leaves pointed but not prickly, persisting 3-4 years ; cones large and long (COMMON SPRUCE).

(b) Leaves pointed, prickly and more silvery below, persisting 2 years ; cones smaller and less compact (MENZIES OR SITKA SPRUCE).

- (2) Leaves 2-sided, with two white lines along lower surface ; defoliated twigs smooth, leaf-scars not prominent ; seed-bracts long and pointed, and protruding above cone-scales.

(a) Leaves stalked, leaf-scars oval ; cones pendulous when ripe, and scales persistent 3. DOUGLAS FIR.

(aa) buds glossy, and rich dark red-brown ; leaves usually dark-green ; cones larger, less evenly conical, and bracts less exserted and reflexed : PACIFIC, OREGON, OR COASTAL VARIETY.

(bb) buds dull, pale, light reddish-brown ; leaves usually light-green ; cones smaller, more evenly conical, and bracts more exserted and reflexed : COLORADO OR INLAND VARIETY.

(b) Leaves sessile, leaf-scar circular ; cones erect, and scales shed with seed in October 4. SILVER FIR.

- 2. DÉCIDUOUS TREES, with leaves clustered in tufts on short shoots, but single on long shoots ; cones ripening in year of flowering ; seed-bracts short, and not showing above cone-scales ; cone-scales persistent 5. LARCH.

- (1) Leaves darker, and turning pale-brown in autumn; shoots yellowish and ashy-grey; cones $1\frac{1}{4}$ - $1\frac{1}{2}$ in. long, with hard stiff scales: COMMON LARCH.
- (2) Leaves paler and longer, and turning pale-yellow in autumn; shoots light brownish-red; cones $\frac{3}{4}$ -1 in. long, with soft scales bent outwards at tip: JAPANESE LARCH.

II. EVERGREEN TREES, with small imbricated leaves and monœcious flowers; male catkins with 4 anther-cells to each scale; fruit a small woody globular or oblong cone, with scales arranged oppositely and alternately (CUPRESSINÆ):—

A.—Twigs round or 4-seeded; cones globular; cone-scales with broad hobnail-like tips, and edges not overlapping (*Cupressus*).

1. CYPRESS.

1. Cones dark-brown, ripening in second year, clustered 3 or 4 together, $\frac{3}{4}$ to 1 inch in diameter, each with 10 scales:

LARGE-CONED CYPRESS.

2. Cones round, and covered with glaucous bloom while young, ripening in year of flowering, solitary, terminal, light-brown, about size of a large pea, and usually with 3 seeds under each scale.

(1) Cones with short stalk, and usually 6 scales: LAWSON'S CYPRESS.

(2) Cones almost sessile, and usually with 6 or 8 scales; twigs with 4 more or less pronounced ridges: NOOTKA CYPRESS.

B.—Twigs flattened, and leaves broader than in the Cupresses; cones small, pale reddish-brown, oval, tapering to both ends, solitary and terminal; cone-scales with edges slightly overlapping (*Thuja*) 2. THUJA OR RED CEDAR.

Historical.—The British Isles were probably at one time mainly covered with primeval woods, most of which were likely destroyed by fire; and wherever the Scots Pine, our only indigenous conifer timber-tree, was the chief tree in mountainous tracts, such fires left the hillsides bare and barren, as Pines cannot reproduce themselves by stool-shoots or suckers, like broad-leaved trees. In the history of Forestry in Britain three main periods are easily distinguishable: (1) up to 1482, when the *Statute of Enclosure* was passed; (2) from 1482 to 1866, when the import duty was taken off foreign timber; and (3) from 1866 up to the present time, when State Afforestation on a large scale is receiving attention.

(1) In early times, throughout England, and to a less extent also in Scotland and Ireland, the chief use of the woodlands was for hunting and for the pannage or feeding of large herds of swine. In 1066 William the Conqueror found great tracts of woodlands and agricultural lands and villages reserved as royal hunting-grounds for the Saxon kings, and he extended the boundaries of these and called them *Forests*, two of the largest being the New Forest in Hants and the Forest of Dean in Gloucestershire, which were both formed before 1086. All lands thus set apart for the king's red deer were said to be "afforested"; and new *Forest Laws* were applied to the administration of these royal forests, of a far more stringent and cruel kind than had previously obtained under Saxon and Danish rule. The cruel oppression of the people whose lands were afforested increased under William II., Henry I., and Stephen. Henry II. made extensive new afforestations, but was forced to relax the severity of the Forest Laws by the passing of a statute known as the *Assize of Woodstock*, 1184. This placed the Forest Law upon a definite footing and made it independent of the Common Law. Special Forest Courts were ordered to be held regularly for each forest, the *Woodmote* every forty days, the *Swainmote* thrice a year, and the *Justice Seat* or *Eyre of the Forest*, the highest court, once every third year, though in course of time irregularities and abuses crept in. In 1215 Magna Charta modified the Forest Laws, and in the time of Henry III. (1216-72) new charters were obtained, as also during the fourteenth and fifteenth centuries, when those owning or holding land in or near a royal forest were subject to vexatious oppression. This state of affairs went on, with modifications, till 1640, when the *Act of Limitation of Forests* was passed, which virtually abolished the Forest Courts, although the office of Chief Justice in Eyre was only terminated by Act of Parliament in 1817, when his duties were vested in the first Commissioner of Woods and Forests. What still remains of these ancient royal forests

are now administered by the Commissioners under an Act of 1852.

In Scotland there were also Forest Laws which seem to have been introduced at a comparatively late date, and to have been formed somewhat on the English model, though far less cruel and oppressive.

(2) **The Statute of Enclosure, 1482**, applied only to the royal forests, chases, and purlieus or disafforested lands in England, and permitted landowners having woodlands therein to fence their coppices against deer and cattle for 7 years after each fall. But even at that early time the fear of a serious want of timber began to be felt; and this gradually grew to such an extent that a *Statute of Woods* was passed in 1543, by which it was decreed that all woods throughout England should be enclosed for 4, 6, or 7 years after each fall of the coppice at under 14, 14 to 24, and over 24 years' rotation, and that at least 12 standards per acre should be "stored" or left to grow into timber. These stores or standards were to be of Oak if possible, but otherwise of Elm, Ash, Aspen, or Beech, the kinds of timber then prized most highly; and they were not to be cut until they reached a given age or a given girth. The operation of this and of similar but modifying subsequent Acts of Parliament was the enforcement of a definite national system of Arboriculture, in the shape of coppice with standards, for growing timber-trees of Oak, Ash, &c., over an underwood of Oak, Ash, Hazel, Chestnut, Birch, Willow, Dogwood, &c., the chief object being the production of timber for the navy and the merchant fleet. This national system of Arboriculture tended to produce great branches and big crooks and curved timber suitable for ship-building. One result of this old practice has been that every one concerned in growing timber became convinced of the necessity for giving each individual tree a more or less free and isolated position; and in more recent times this principle was also applied to a greater or less extent to timber-crops grown as highwoods, and

therefore really needing to be kept in fairly close canopy. It thus led to habitual overthinning tending to stimulate excessive branch formation at the expense of a long and clean stem. And as the market for oak-bark and small coppice-wood is now very poor compared with what it used to be, many of the old coppices, with or without standards, have been or are in course of being converted into highwoods. But it is important to note at the outset that the tendency to overthin greatly, which is now usually admitted to be one of the great faults in British Arboriculture, had its origin in 1543, when the Statute of Woods ordained for England the coppice-with-standards system of growing timber-trees, and that this system was continuously developed and enforced by subsequent Acts of Parliament.

During the most of this second period, from 1482 right up to about 100 years ago, there was always a dearth of timber, and especially of oak, owing to the constantly growing demands for ship-building and other constructive purposes. But when timber-importation began on a large scale early in the nineteenth century, after Britain had obtained the command of the seas, less attention than hitherto was paid to home forestry, which began to decline rapidly as improved steam communications developed by land and water. The growing neglect became greater when the import duty was taken off colonial timber in 1846; and when the import duty was also removed from all foreign timber in 1866, thereby cheapening the price of the fine clean-grown stems and excellent sawn wood arriving in apparently inexhaustible abundance, the value of home-grown wood fell so low that timber-growing, for centuries an important rural industry, became unprofitable, and many of the existing woodlands came to be practically treated mainly as game coverts and ornamental parts of the large landed estates. The removal of the foreign import duty in 1866 virtually gave the death-blow to the old national system of Arboriculture that sprang up in England from 1543 onwards, and then extended to Scotland, and which had

also been introduced into Ireland from and after an Act of 1634. But the growing demand for timber throughout the world's greatest industrial countries, and the simultaneous rapid exhaustion of the hitherto cheap and easily obtainable supplies, have again recently revived the interest in timber-growing in Britain; and the modern system of Forestry upon *syllvicultural* rather than *arboricultural* lines, that has of recent years been gaining ground in the United Kingdom, is mainly the adaptation of such Continental and especially German methods as seem suited to our very different economic conditions.

(3) **The third period, from 1866 onwards.**—After the Civil War ended in 1867 the population and the commerce of the United States of America began to increase rapidly; and shortly afterwards similar developments commenced in Germany, after the formation of the German Empire in 1871. Up till then Britain was by far the greatest industrial country in the world, and could easily get all the timber it wanted from America, Norway and Sweden, Russia, &c. But now the United States and Germany need far larger quantities of wood and timber than they produce, and are our competitors for the surplus supplies of the great wood-providing countries, such as Canada and Russia. But even in these still well-wooded countries less timber is available than formerly, and the cost of extraction is greater, so that prices have risen greatly and have constantly an upward tendency. Hence it now seems very important that Britain should endeavour to adopt some well-considered national scheme of timber-planting, in order to secure the steady supply of at least a part of her annual requirements in timber and other wood in years to come. The United Kingdom only contains about 3,030,000 acres of woodlands; and for the most part these are ornamental or mainly for shelter and sport, and have not, of recent years at any rate, been worked upon commercial lines. Then, too, the market has changed with regard to what was habitually grown for the home

demand. Curved oak is not much needed for ship-building, nor is oak-bark much used for tanning; small coppice-wood, formerly required for hop-poles, hurdles, &c., is now hardly saleable at all; and birch and alder, once greatly in demand for gunpowder charcoal, is no longer used in large quantities.

Several Committees have during the last 25 years been appointed to deal with Forestry; but, so far as planting is concerned, only little practical result has come of these inquiries. In 1887 a Parliamentary Committee made recommendations which were not acted on; and in 1902-3 a Departmental Committee of the Board of Agriculture reported on the subject. It refrained from recommending any great national scheme of planting, but advocated more and better instruction in Forestry; and lecturers have since then been appointed at Newcastle, Bangor, Glasgow, Aberdeen, and other collegiate centres, whereas previously the only collegiate course of lectures had been given at Edinburgh University (since 1889).

In 1904 a school for Forest Apprentices was opened in the Forest of Dean (Gloucestershire) by the Commissioners of Woods and Forests, and in 1905 a similar Forest School was organised at Avondale (Co. Wicklow) by the Department of Agriculture in Ireland; but as yet no such school has been founded for Scotland, although it contains far more plantable land than England, Wales, and Ireland all taken together. In 1908 a Committee appointed by the Department of Agriculture in Ireland recommended an extensive scheme of planting 700,000 acres in Ireland; and in 1909 the Royal Commission on Coast Erosion and Afforestation issued a report recommending a vast scheme for the planting of 9,000,000 acres by the State, of which 6,000,000 were to be in Scotland, and the remaining 3,000,000 in England, Wales, and Ireland. Of our existing 3,030,000 acres of woods and plantations, 97·7 per cent belong to private owners, and 2·3 per cent to the Crown, being mostly remnants of the ancient royal forests; but except as regards some recent purchases made by the Department in Ireland, the

State owns no woodlands whatever; there is not a single acre of State woodland in Great Britain. Experimental planting is likely to be done soon under the Development Act, 1909; but before any very extensive national scheme of planting can be successfully begun in Scotland, where most of the plantable land is admitted to be, a well-equipped School for Forest Apprentices is just as necessary as the large funds that will be needed for such a large permanent investment. The importance of trying to do something to provide for our future requirements in timber and wood-produce can easily be judged of from the fact that both in 1906 and in 1907 our gross imports of wood and timber, wood-pulp and manufactured wood-pulp, amounted in value for each year to over £37,378,000, while the total for wood and timber alone totalled over £29,013,000 in each year. As comparatively little of this is re-exported, these figures show the vast field open to timber-growing — whether mainly by private landowners with State encouragement and assistance, or directly by the State, or by some such combination of State and private efforts as obtains in France and Germany. Over nine-tenths of our wood imports are of coniferous timber, which is just the class of trees that can be grown most conveniently and successfully on our poor and waste lands, aggregating over 16½ million acres. Britain is, in fact, one of the most poorly wooded countries in the world, the land statistics being as follows (in acres in round numbers):—

	Land Area.	Woodlands.	Mountain and Heath.	Percentage.	
				Woodland.	Wasteland.
England.	32,381,051	1,666,000	2,306,000	5·1	7·1
Scotland.	19,069,010	879,000	9,375,000	4·5	48·1
Ireland.	19,322,798	303,000	3,780,000	1·5	18·5
Wales.	4,748,109	182,000	1,251,000	3·8	26·2
Total.	75,520,968	3,030,000	16,712,000	3·9	21·6

The Climatic and Physical Effects of large compact blocks of woodland consist in tending (1) to equalise the temperature both of the soil and of the atmosphere, and to diminish extreme differences in each of these during summer and winter ; (2) to increase the relative humidity of the air, and also perhaps slightly increase the total amount of dew, mist, and rainfall ; (3) to absorb and retain moisture in the soil, and especially in the upper layer of humus, thus helping to prevent floods, to maintain the perennial flow of springs and brooks, and to act as purifying filters in water-catchment areas ; (4) to protect the surface-soil from erosion during heavy rainfall ; and (5) to help to purify the air from excess of carbon-dioxide.

Their Economic Uses are (1) to provide work for part of the rural population, and especially during winter, when other work is scarce ; (2) to provide part of the timber now imported in vast quantities for industrial purposes, and thus increase the sum total of wages payable to workmen in our own country ; (3) to give shelter to fields and farm live-stock ; and (4) to add to the attractions of country life by increasing facilities for sport. On the average every 100 to 150 acres of woodland provide permanent work for one woodman ; but this gives no indication of the total amount of employment of various kinds that large woodlands worked on business principles would ensure to the rural population in planting, tending, and felling timber-crops, in preparing, extracting, transporting, and converting the timber, and in distributing the converted timber and other woodland produce. Under a great national scheme of afforestation many million pounds sterling would in course of time be circulated among our own rural population, in place of being paid to foreign workmen as at present. Even 3,000,000 acres of well-managed coniferous timber-crops worked with a rotation of 60 years would give an annual mature fall of 50,000 acres, besides thinnings from younger woods, and would probably yield on the average a total crop of about 100 tons weight of timber per acre,

or about 5,000,000 tons of raw material having to be cut, dressed, transported, converted, and distributed; and this all means wages that might be earned and circulated here, instead of the money being sent abroad in payment for foreign labour.

The Growth of a Tree.—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, after assimilation of atmospheric carbon-dioxide through the foliage, under the action of sunlight and warmth.

A tree consists of an overground *bole* or *stem*, with large and small *branches*, *twigs*, and *shoots*, bearing the crown of foliage, and an underground root-system consisting of a *tap-root* or central axis, *side-roots*, *fibrous-roots*, and *suction-rootlets* with one-celled *root-hairs* for imbibing water and soluble plant-food from the soil. Even in trees with a pronounced tap-root (Oak, Larch, Pine) there is no underground stem before the root-system begins to branch; but the development of the root-system always depends greatly on the physical condition of the soil and on the leaf-area of the crown of foliage.

A young tree is produced naturally by seed from a parent tree germinating under the influence of warmth, moisture, light, and air. By absorbing moisture its tissue softens and stretches, while the water is partly decomposed and partly used in transforming the starch-reserves stored up in it and converting them into grape-sugar (when *starch*, $C_6H_{10}O_5$, + *water*, H_2O , becomes *grape-sugar*, $C_6H_{12}O_6$), by means of which the embryo begins to grow when the weather gets warm enough.

The embryo grows downwards into the earth by a young root, and upwards into the air by the seed-leaves. The young root lengthens, and through its root-hairs absorbs mineral food, dissolved in the soil-moisture, which is conveyed upwards by the cellular tissue and exposed in the seed-leaves to the action

of light and air. Here water is transpired and nourishment prepared for further growth by the assimilation of atmospheric carbon and the formation of carbo-hydrates. As the current of sap keeps rising from the roots to the growing-point, a small shoot forms, which aërates the sap and sends it downwards; and as the elaborated sap descends, woody matter is formed in the centre of the radicle, thus enabling it to ramify, while woody matter is also gradually formed within the vessels of the young plant by the deposition of elaborated matter. The growing-point then acquires the rudimentary form of a *leaf*, and develops until the first leaves are completely formed to carry on more easily the functions previously performed by the seed-leaves. Assimilation then becomes more vigorous, and the sap is elaborated in larger quantity, conveyed downwards through the cambium, and deposited as cellulose, part being incorporated with the bark, and part forming sapwood. And as the cellular tissue of the stem is also expanding to make room for the matter passing into it, perpendicular and horizontal development go on simultaneously. Young roots are also formed, which increase and branch by constant gradual increment; and thus a natural balance is maintained between the root-system and the leaf-area for which water and mineral food have to be provided, and on whose assimilative power increment depends.

Other leaves appear, all formed like the first, and performing similar functions; and at last the growing-point or axis ceases to lengthen for the season, and the old leaves 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 a new growing-point and become the scales of a *leaf-bud*.

With the return of warm weather in the second spring the flow of the sap takes place and active vegetation recommences. The buds gradually unfold when the water containing mineral food ascends, and the sap utilised is instantly replaced by

continuous supplies from below ; the root-system extends by new suction-roots being formed ; fresh food-supplies are absorbed and sent upwards through the soft sapwood ; and active vegetation continues till autumn, the food-supplies transmitted to the leaves being there subjected to the chemical action of light and transformed under the processes of assimilation of atmospheric carbon and preparation of carbo-hydrates, and the elaborated food returned down through the *cambium* to form a new layer of *sapwood* on the woody fibrous tissue and of *bark* on the outer protective cuticle. By the end of the year the phenomena of the previous season have been repeated ; ligneous matter has been gradually produced during 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 the winter period of rest from active vegetation ; and the stem has grown in diameter.

During the third year similar processes are repeated on a more extensive scale. More roots and rootlets are formed ; food-supplies are absorbed and elaborated in larger quantities ; new cambial layers are formed on the wood and the bark, and the horizontal and the perpendicular developments of tissue are continued ; and another annual ring is added to those of the two previous years. And thus year after year the tree continues to grow till it is felled, or till its active functions cease through old age and death, or disease, or accident.

The Nutrition and the Growth of Trees depend partly on physical and climatic, and partly on chemical conditions. The essential physical factors are *Warmth* and *Light*, and the chemical factors *Oxygen*, *Carbon-dioxide*, *Nitrogen*, and *Water*, together with mineral substances absorbed from the soil in the form of soluble nutrient salts. Where all these factors are combined favourably for the requirements of any individual kind of plant, it can thrive well ; but where any one factor

is unfavourable, it will either show poor growth or be unable to grow at all. Hence timber-crops, like field-crops, are subject to what is known as the *Law of the Minimum*, according to which "the total extent of production depends upon whatever essential factor is present in the lowest degree"—no matter how favourable may be the combination of any or all of the other factors. *The mineral food of trees* includes potash, lime, magnesia, iron, sulphur, phosphorus, and 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 burning. But the different physiological uses of these mineral substances are not yet clearly understood.

Experience shows that timber-crops of one kind or another can be profitably grown on any kind of land that is neither too dry nor too wet. Most kinds of soil contain sufficient mineral food to enable tree-crops of any kind to grow; but there is not always sufficient soil-moisture to hold it in solution so as to make it available for absorption by the root-system, and when the land is too wet there is a deficiency in oxygen. Thus depth and porosity are of more importance than chemical composition. On the other hand, a rich soil furnishing copious food-supplies will produce large crops of timber, but it will be soft, spongy, and not so durable as timber with denser and more compact annual rings.

Soil cannot always be classified according to its geological origin; because the same kind of rock does not always decompose into similar soils, and its productivity depends on the extent of its decomposition, while 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 (silica). This includes *sand-drifts*, *sand*, and *loamy sand*.

Loamy Soil, containing 60 to 70 per cent of fine sand, the rest being

chiefly clay and less than 5 per cent of lime, with about 5 per cent of ferric oxide as colouring matter. This includes *loam* and *sandy loam*.

Clayey Soil, containing 50 per cent or more of clay. This includes *clay* and *loamy clay*.

Limy Soil, with 10 per cent or more of carbonate of lime. This includes *lime*, *clayey lime*, *loamy lime*, and *marl*.

Sandy soil feels gritty when slightly moistened, is easily heated or cooled, does not well retain moisture and soluble plant-food, and is therefore an inferior soil, on which trees need a large growing-space, do not maintain close canopy, soon fall off in rate of growth, and produce little seed. 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 exposed to damage by late frost.

Clayey soil sticks to the tongue, smells of ammonia if breathed upon, feels fatty if rubbed between thumb and forefinger, and takes a polish if rubbed with the thumb-nail. It is usually tinged with iron, and of a grey, yellow, or brownish-red colour. It is cold, stiff, impermeable to moisture, and apt to get water-logged and marshy. Admixture of sand tends to modify these characteristics. As soluble salts are not easily washed out, clay soil contains large food-supplies, and tree-crops have a better leaf-canopy than on sandy soil. Owing to low conductivity of heat the active vegetation is late of beginning in spring.

Limy soil effervesces if nitric acid be dropped on it, and is apt to be shallow; but woods in close canopy often show fine growth. When limy soil has deteriorated through insufficient leaf-canopy or clear-felling, the soil-moisture soon evaporates, the finer earthy particles are washed away, and the soil becomes shallow, dry, hot, and unproductive.

Loamy soil resembles clay more than sand, but 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, in which the absorption and retention of soil-moisture depend greatly on the nature of the subsoil; and it is suited for growing almost every kind of tree.

Any of the above soils may also be gravelly or stony.

The Physical Properties of Soil, which are far more important than its chemical or mineral composition, and all of which, with their innumerable variations, act and react on each other in determining the quality of any given land, include (1) *Depth*, (2) *Stiffness*, (3) *Soil-moisture*, and (4) *Soil-temperature*.

(1) **Depth** is the extent to which soil is decomposed before a practically unaffected **subsoil** is reached, which may, or may not, be of a different kind from the soil above it. As regards depth, a soil may be classed as *deep*, *medium*, and *shallow*.

Depth of soil is very important for trees like Oak, Sweet-Chestnut, Larch, and Pines, which form a deep-going tap-root, because the growth in height soon falls off if the root-system cannot develop normally. Trees with fairly deep root-systems, like Beech, Ash, Elm, Maple, and Sycamore, Silver Fir and Douglas Fir, and even shallow-rooting kinds like Birch, Aspen, and Spruce, all thrive better on deep than on shallow soil. The disadvantages of a shallow soil are all the greater when the subsoil is a stiff clay or impermeable, and tending to make the soil-water stagnate. Deep soil produces a long, clean bole, shallow soil a short stem with a big, branching crown.

(2) **Stiffness**, the resistance offered to separation or disintegration of the soil particles, is important in relation to air, moisture, and warmth, and on it also depends the resistance to be overcome by roots in penetrating and ramifying throughout the soil.

Clay soil is the stiffest, *sand* the loosest or lightest; *lime* is more like clay, and *loam* more like sand. An admixture of *humus* or leaf-mould makes clay and lime less tenacious, and stiffens loam and sand, besides yielding ammonia-compounds and assisting in the beneficial processes of nitrification and denitrification. The liability of soil to expand after rainfall and to shrink during drought is practically proportional to its stiffness. Soil may be distinguished as *heavy or stiff* (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 and fairly moist soil produces most rootlets and foliage, and consequently most timber.

(3) **Soil-moisture** is essential for tree-growth, because only soluble salts can be imbibed by the suction-roots, and neither transpiration nor assimilation could possibly take place without it. It helps to regulate soil-temperature, and to prevent sandy soils heating or cooling too rapidly. But too much soil-moisture leads to the formation of injurious acids and of marshes, interferes with aeration of the soil, and both retards vegetation and increases danger from frost. A soil may be *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 and White Alder on limy soil, can there best accommodate themselves.

(4) **Soil-temperature** depends greatly on the quantity of moisture and the colour of the soil. Clay soil is cold and inactive ; but once heated, it cools gradually. Sand or gravel is easily warmed, but cools rapidly, and in damp localities this increases the danger from frost.

Climate or the Influence of Situation affects tree-growth in a very marked degree, though the several factors—(1) *temperature and humidity in atmosphere and in soil*, (2) *amount and intensity of sunlight*, (3) *aspect or exposure towards N., E., S., or W.*, (4) *slope or gradient of hillsides*, and (5) *shelter from strong winds*, due to the local configuration of the land and the surrounding country—all act and react on each other, and also in conjunction with the physical properties of the soil, in such a way as often to obscure the causes why any particular kind of tree may perhaps not thrive in any given situation.

The Sylvicultural Characteristics of Trees are (I.) their special peculiarities regarding climate, soil, and situation ; light and shade ; shape of root-system, stem, and crown ; rate of growth ; reproductive and regenerative power ; and maturity and longevity ; and (II.) their general characteristics as woodland crops, in consequence of these special peculiarities.

(1) *As regards climate or temperature and rainfall*, each kind of tree has a northern and a southern limit determined by winter cold and summer heat or drought, and also a limit of altitude in mountain-tracts determined by cold. But owing to geographical conditions and local configuration, there are no hard-and-fast lines of demarcation throughout Western Europe in either of these respects. Our mild equable climate is well suited for all the Central European trees, and many North American trees also thrive well here. Nor are there any well-marked zones of elevation, as shelter from strong winds is a very important factor in this respect. But of our common woodland trees, experience shows that Birch, Scots Elm, and Scots Pine grow better in Scotland than in the South of England ; that Beech, English Elm, Pedunculate Oak, Chestnut,

Willows, Poplars, and Weymouth and Maritime Pines do best in the warmer parts of England ; that Alder, Ash, Pedunculate Oak, English Elm, Maple, Willows, and Poplars thrive best on low-lying land ; and that Scots Elm, Sessile Oak, Sycamore, Scots Pine, Spruces, Silver and Douglas Firs, and Larch do best in the north of Britain and on hilly land. A damp climate suits Spruce, Red Cedar, Pacific Douglas Fir, Beech, Wych Elm, and Sycamore ; while Larch, Scots and Black Pines, Colorado Douglas Fir, Oak, and Common Elm prefer a dry climate. Beech, Ash, Chestnut, Robinia, Menzies Spruce, and Silver and Pacific Douglas Firs are most liable to damage by frost ; while Aspen, Birch, Elm, Hornbeam, Lime, Sallow, Larch, Spruce, Colorado Douglas Fir, and Red Cedar are the hardiest against winter cold and late frosts ; though all kinds are more likely to be nipped by late frost when growing on land exposed to the early morning sunshine. Common Spruce and Common Larch are hardier than Menzies Spruce and Japanese Larch.

(2) *As regards soil and situation*, with increasing altitude the temperature falls and the air becomes moister, but this is not very marked in our generally damp climate. Conifers generally are less exacting and have a greater accommodative power than broad-leaved trees as to moisture and mineral food, the most accommodative being Aspen, Birch, Sallow, and Scots Pine, and the least accommodative Ash and English Elm. Depth, permeability, and a moderate amount of moisture are of more importance than any particular kind of soil ; for it is of greater physiological advantage that the root-system of any tree should develop freely and normally, and that the situation should (as regards climate, natural drainage, aspect, &c.) be suitable, than that the soil itself should be sandy, loamy, clayey, or limy. With favourable physical properties any soil will furnish sufficient plant-food for good tree-growth ; but Oak, Ash, Elm, Chestnut, Maple, Sycamore, Larch, Douglas

Fir, Silver Fir, and Scots Pine have the deepest roots, and therefore need a deep soil for healthy growth ; while Aspen, Birch, Willow, Poplar, and Spruce have only a shallow root-system, but also grow better in a deep than in a shallow soil. Beech, Ash, Elm, Maple, Sycamore, Hornbeam, White Alder, Oak, Austrian Pine, and Larch thrive on limy soil ; but much lime acts injuriously on Sweet-Chestnut, Douglas Fir, and Maritime Pine. *Humus* or leaf-mould improves all kinds of soil ; hence replantation on true "woodland soil" is usually more successful than the first planting of waste lands and poor pastures, in which there is probably a deficiency of nitrogen in an easily available form.

(3) *As regards light and shade*, trees are classifiable as *light-demanding* and *shade-enduring*, according to the amount and the intensity of sunlight needed for the assimilation of carbon and the elaboration of the sap—the demand being apparent from the amount of foliage borne by the tree-crown (which, of course, varies with the situation and the quality of the soil). The light-demanding trees most intolerant of shade are Larch, Birch, and Robinia ; Pines, Poplars, and Willows ; Oak, Ash, Elm, and Chestnut ; less intolerant of shade are Alder, Lime, Horse-Chestnut, Maple, and Sycamore ; while Beech and Hornbeam, and most evergreen Firs and Cypresses (especially Spruce, Douglas and Silver Firs, and Red Cedar) are shade-enduring, as also the stool-shoots of the kinds of trees usually grown as underwood in copses. All our woodland trees thrive best with their crown of foliage freely exposed to sunlight ; but Beech and Silver Fir seedlings need protection against scorching and frost for the first two or three to four or five years, and are therefore usually naturally regenerated under parent standard trees. But the poorer the soil, the greater is the demand for light, and the less the tolerance of shade. Young Sycamore and Ash springing up self-sown can tolerate heavy shade at first. In trees the capacity for tolerating shade is shown by

the thickness of their foliage and by the length of time over-shadowed twigs of evergreen Conifers retain their leaves.

(4) *As regards root-system, stem, and crown*, trees grown as woodland crops have always a smaller growing-space than when growing freely in the open ; but while the roots and the crown are kept smaller, the growth in height (due to the struggle for existence) is greater, and there is less tendency to spread side-wards into branches. And, of course, it is only when deep-rooting and light-demanding kinds of trees have their natural requirements satisfied that good growth can be maintained, and more especially as the trees approach maturity.

(5) *As regards rate of growth* as timber-crops, few of those which grow rapidly in height at first furnish very large mature crops, though the Pacific Douglas Fir and Menzies Spruce are exceptions in this respect. Among European trees the largest crops per acre are yielded by Silver Fir and Spruce, though both are slow in establishing themselves and beginning to shoot ahead. *Increment or growth in cubic contents* is the combination of growth in height and growth in girth. As the number of stems per acre has to be sooner lessened (by thinning) to provide the necessary growing-space, light-demanding trees culminate in increment and become less energetic sooner than shade-bearing trees, though, of course, much depends on the soil and situation. Hence shade-enduring trees (Douglas Fir, Spruces, Silver Fir, and Red Cedar ; Beech) produce larger crops per acre than light-demanding trees (Larch and Pines, most hardwoods and soft woods), and larger crops are usually obtainable on a fresh than on a dry soil, in which food-supplies are scarce.

(6) *Reproductive power* in throwing up stool-shoots and root-suckers and *Regenerative power* in producing seed are different forms of utilising reserve nutrients, in the one case for maintaining individual life, and in the other for propagation of the species. Reproduction is strongest in the younger stages of

growth, and falls off when the seed-producing stage is entered. Oak, Beech, Elm, Ash, Maple, Sycamore, Chestnut, Hornbeam, Lime, Alder, and Birch mainly produce stool-shoots; while Aspen, Robinia, Rowan, non-indigenous Willows and Poplars, and White Alder mainly produce root-suckers. But Chestnut, English Elm, and Lime also throw up a good many suckers, which can be severed and transplanted like seedlings; and they can easily be propagated by layering, while Willows and Poplars can easily be raised from slips or cuttings.

In seed-production, trees bearing small fruits with small seeds are much more prolific than those bearing large fruits with heavy seeds. They seed more frequently, and the seeds are carried farther by wind; hence, even though the germinative power of their seed be less, the average regenerative power of Willows, Poplars, Alder, Birch, Scots Elm, Maple, Sycamore, Pines, Spruces, Douglas Fir, and Cypresses is greater than in Silver Fir, Beech, Oak, and Chestnut. Seed-production is most prolific when trees have completed their main growth in height and begun to expand their crown, as their vital energy is then greatest. Good soil, warm situation, and a free growing-space favour seed-production. Birch, Alder, Larch, and Scots Pine begin to bear seed at about twenty years of age, but Oak and Beech not until about the sixtieth year. 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. 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, while Ash, Hornbeam, Maple, and Sycamore seeds may germinate freely only in the second spring.

Some idea of average regenerative power may be formed from the following table, but both the size and the weight of the seed, and also its germinative capacity, depend greatly upon the quality of the soil and situation, and upon favourable climatic conditions:—

Kind of Tree.	1 lb. cleaned seed contains about	Ordinary Germin- ative capacity about	Ordinary No. of seedlings from 1 lb. of clean seed, about ¹	Time ² usually needed for germin- ation.
	Seeds.	per cent.		Weeks.
Birch	700,000	10	70,000	3-5
Alder	300,000	15	45,000	3-5
Elm	60,000	15	9,000	2-3
Hornbeam	13,000	50	6,500	3-5 ³
Ash	7,000	50	3,500	4-6 ³
Maple and Sycamore	6,000	50	3,000	4-6 ³
Beech	2,000	60	1,200	3-4
Oak, Sessile	150	60	90	4-6
Oak, Pedunculate	125	60	75	4-6
Chestnut	100	60	60	3-6
Red Cedar (<i>Thuja gigantea</i>)	300,000	20	60,000	2-4
Menzies Spruce	180,000	20	36,000	3-5
Larch, Japanese	100,000	15	15,000	3-5
Scots Pine	75,000	50	37,500	3-5
Larch	70,000	30	21,000	3-5
Spruce	64,000	50	32,000	4-6
Douglas Fir	40,000	30	12,000	3-4 ³
Austrian and Corsican Pine	25,000	30	7,500	2-4
Silver Fir	10,000	30	3,000	3-6

(7) *Maturity and longevity* vary greatly in our woodland trees (up to more than 500 years for Oak and Chestnut); but timber-crops reach their marketable or financial maturity at a comparatively early age, and earlier on poor than on good soil, varying from 35 to 50 years for softwoods, 40 to 70 for Conifers, 60 to 100 for most hardwoods, and 100 to 150 for Oak. Thus two or three conifer crops may be taken for one of Oak; and

¹ Many of these die off, and only a much smaller number is fit to line out as transplants.

² Germination is hastened by soaking the seed in water, but this makes sowing more difficult and less even and regular.

³ Also partly not till second year, especially if sown deep.

this is not the least of the advantages promised by growing conifer crops suitable for any given soil and situation.

The following may serve as rough averages as to the rotation in which timber-crops can usually be most profitably worked in Britain :—

Kind of Timber-crop.	On good soil, and in a favourable situation.	On poor soil, and in an un- favourable situation.
Birch, Willow, Poplar Larch, Pines, Spruce and Red Cedar } Ash, Elm, Maple, and Sycamore } Douglas and Silver Firs Beech Oak	Years. 40-50 60-70 70-80 100-120 120-150	Years. 35-45 45-60 50-60 90-100 90-120

But a wood that has been heavily thinned will mature (financially) sooner than one kept in close cover; and if not then cleared, both the crop and the soil will deteriorate.

General Characteristics or Habits of Growth as Woodlands Crops arise from the combined influence of the above special characteristics when large masses of trees are collected together, for each kind of tree then assumes a definite relation towards itself and towards other trees, and becomes either *gregarious* or *sporadic* in habit. Gregarious trees tend to *predominate* throughout the whole woodlands, and to form *pure woods* unmixed with other trees; while sporadic trees are more or less scattered and *subordinate* in number, and thrive best when scattered throughout *mixed woods*, either as single stems or in small patches (*e.g.*, the Larch, in the Alps), and are *dependent* on the gregarious trees for maintaining the productivity of the soil. Other things being equal, shade-enduring trees would gradually, in course of time, oust light-demanding trees, and become ruling species over large areas, as where the Silver Fir, the Beech, and the Spruce form large and more or less

pure forests in Central Europe. But other things are never equal in nature; and trees having light and winged seeds, especially hardy kinds that grow quickly at first (*e.g.*, Birch and Aspen), often establish themselves securely before the kinds previously on the ground have been able to regenerate themselves, so that a mixture of trees varying according to soil, climate, and situation is characteristic of all natural woodlands, and is the safest method to adopt in forestry.

Pure Woods can be formed by all kinds of shade-enduring trees, because their dense overshadowing and large fall of dead leaves both preserve and usually increase the soil-productivity. This is also the case with Pines, under which thick moss springs up when the trees begin to thin themselves; but this mossy protection disappears as the crop ages and the leaf-canopy becomes more and more broken. But much less soil-protection is afforded in the case of light-demanding 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 underplanted*; (2) *when the soil-productivity 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); or (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.*, Pine on poor, dry sand; Austrian Pine on deteriorated lime; Ash-groves and Alder-beds on wet land). Practically, however, it often happens that only one sort of wood is saleable at a fair profit, and then, if he plant at all, the landowner may prefer to plant that (*e.g.*, pure Larch, despite the risk there always is of canker). The most suitable trees for pure woods are Beech and the shade-enduring ever-green Conifers (Spruces, Silver and Douglas Firs, and Cypressess).

Mixed Highwoods are on the whole preferable to pure woods,

and usually produce timber of the largest size and best quality, except where the soil and the situation distinctly indicate one kind of tree as preferable to any other and most likely to thrive in large masses. Nature's method in great virgin forests is that the different kinds of trees usually occur either scattered more or less sporadically, or else in large or small family groups, except where some chance circumstance connected with the production and distribution of seed, reproductive power, endurance of shade, hardiness, or peculiarity in soil (especially as regards moisture) and situation has enabled one kind to become more or less dominant over large areas, to the suppression of other kinds of trees less able to assert their position and maintain themselves under the given conditions. Where Beech is dominant, nearly all other kinds of trees grow better when mixed with it than they do in pure crops or mixed among each other only. The British custom of mixing Larch and Scots Pine along with Spruce and Douglas Fir in alternate rows is not advisable; for although the former usually shoot ahead at first, they are generally caught up at about 15 to 20 years of age, and then suppressed. Mixture of Larch and Spruce also tends to increase the aphids (*Chermes*, see p. 226).

The Different Forms of Woodland Crops.—In the Statutes relating to land valuation, rating, and succession duty, and in the Board of Agriculture returns, woodlands are classed either as "*Coppices*" or "*Woods and Plantations*." This is merely a continuation of ancient law and custom, for both under the old English forest law and under the common law applying to lands not included within any forest boundary, the woodlands were either coppices (*sylva cædua*), whether simple or stored with standard trees, or woods (*saltus*); and important legal differences have always existed, and still exist, in England between these two classes of woodland crops on settled estates. Woods or timber come under the ancient English common law, that "whatever is planted on the land, goes

with the land," and forms part of the estate ; and when timber is sold on any settled estate the proceeds from the sale of such timber are treated as capital moneys arising under the Settled Lands Act, 1882 (sect. 35), the heir-in-possession only receiving one-fourth thereof ; while in Scotland an heir-in-possession of an entailed estate can cut the timber without restriction. But from a silvicultural point of view, woodlands may be treated according to one or other of the following different methods :—

I.—COPPICE or COPSE, reproduced chiefly from stool-shoots, and which may be either

1. SIMPLE COPPICE, pure or mixed ; or
2. STORED COPPICE or COPPICE with STANDARDS, preferably raised from seed or from suckers.

II.—HIGHWOODS, which may be renewed either by

1. CLEAR - FELLING, with artificial regeneration by sowing or planting ; or
2. SUCCESSIVE FALLS or PARTIAL CLEARANCES, which may be either
 - (1) OCCASIONAL OR MORE OR LESS REGULAR FALLS THROUGHOUT THE WHOLE WOOD, with natural or artificial regeneration ; or
 - (2) NATURAL REGENERATION IN GROUPS, by felling in patches ; or
 - (3) UNIFORM NATURAL REGENERATION, by means of regular partial clearances made to stimulate seed-production, utilise good seed-years, and gradually remove the mature parent trees when the young crop has established itself, is no longer in need of protection against frost or scorching, and needs more light and air.

1. **Simple Coppices** can be formed of any kind of broad-leaved tree, but no Conifer has sufficient reproductive power to be grown in this way. Sweet-Chestnut, Oak, Lime, Maple, Sycamore, Hornbeam, Ash, Mountain-Ash, Alder, and shrubs like Hazel, Holly, Buckthorn, and Dogwood reproduce themselves better than Beech, Birch, Sallow, and Aspen, though softwoods often become dominant on moist land. The best coppice crop to grow on any given land and the best period of rotation depend mainly on the market available.

Grown chiefly for Oak-bark and charcoal (Birch and Alder) in Scotland and Ireland, they used to be largely cultivated in parts of England where fuel was scarce and hop-poles always in good demand ; but since about 1870 the value of coppices has in most cases shrunk so much that they are now unprofitable.

Osier-holts of the smaller Willows, the most valuable and profitable coppices, are largely grown in the fen districts (Lincoln and Cambridge). The chief kinds cultivated are the True Osier (*S. viminalis*), with thin, tough, flexible withes growing in thick clusters ; the Laurel Osier (*S. triandra*), with long flexible twigs ; and the Purple Osier (*S. purpurea*, from the colour of its male flowers), with very thin and tough withes.

Periodical inundations stimulate the growth of Osiers. Floods in winter do no harm, even if lasting for weeks, but lengthened submersion during summer is injurious. 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.

The cost of preparing and planting Osier-holts is from £14 to £23 an acre, and the crop maturing in four or five years 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). But from the amount of attention it requires, Osier-growing is far more of the nature of Gardening than of Forestry. Coppices of Oak, Ash, Alder, and Osier should be kept pure, and care should be taken to prevent the intrusion of softwood seedlings, which should be weeded out ; but in all other coppices a mixture of different kinds is of advantage, enabling variations in the local market demand and in the quality of the soil to be better utilised.

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 streams is mainly an agricultural measure.

2. **Stored Coppice or Coppice with Standards** grows best when the *overwood* consists of light-demanding trees, and the *underwood* of shade-enduring kinds. The *Statute of Woods* commanded that "12 standils or storers of Oak" were to be left per acre, or, failing Oak, of "Elm, Ash, Asp, or Beech," which were then the most valuable kinds of timber-trees. On good, fresh loam Oak and Ash are still the most valuable standards, while, as in simple coppice, Hazel, Ash, Chestnut, and Sycamore usually form the most profitable part of the underwood. The number of standards that can be left per acre depends on the quality of the soil, but absolute regularity in the different age-classes is never attainable in practice. (See also pages 80, 112).

3. **Highwoods**, usually raised from seed either by natural regeneration or by artificial sowing or planting, are not cleared as a crop until they have either reached their full maturity or are old enough to yield a crop of marketable timber; and it is the only crop-form in which Conifers can be grown. It is also the only form in which long straight clean stems can be produced. Highwoods may be worked with a rotation of from about 40 years (for pitwood) up to 120 years or more (for Oak). Until highwoods are mature the only fellings made in them are *thinnings* to remove dead, badly-grown, suppressed or diseased trees interfering with the growth of others more likely to prove profitable.

Highwoods are usually the most profitable timber-crop, then **Copse or Coppice with Standards**, and simple **Coppice** the least profitable nowadays. But Osier-holts or Alder-coppices for clog-wood prove, under favourable conditions, much more profitable than copse or most kinds of highwood. And copses are attractive to small landowners, both because they lock up far less capital, and also because they form good game-coverts and

fox-preserves. When once simple or stored coppice has been formed, each rotation of 10 or 12 to 20 or 25 years involves only a small outlay in filling blanks, whereas the capital sunk in highwood crops grows at compound interest and increases rapidly, unless there be good thinnings.

Throughout the forests of Continental Europe during the last hundred years or more the artificial growth of pure woods of several kinds of trees (especially Conifers, the most profitable timber-crops) has been greatly encouraged. But in place of this leading to the profit expected, it has only too often led to greatly increased damage and loss of money through insect attacks, fungus diseases, windfall, snowbreak, &c. This has especially been the case with Spruce in Germany, where pure Spruce woods grown at sixty years' rotation on a fresh soil and in a damp climate were reckoned to be the most profitable form of timber-crop. So now the formation of mixed woods is far more in favour than thirty or forty years ago, and endeavours are being made to provide for good mixed woods in the future. But the production of Oak, Ash, Elm, Maple, and Sycamore, and also Larch, has always been most satisfactory in mixed woods of broad-leaved trees, and especially when the chief species is Beech, whose thick fall of dead foliage rich in potash forms the best leaf-mould. The advantages of mixed woods are (1) a thick crop protecting the soil; (2) the production of larger and finer timber; (3) diminished danger of windfall, snowbreak, insects, and diseases; (4) easier natural regeneration; (5) easier introduction of changes affected by market demand, and (6) greater picturesqueness and diversity in foliage tints; while the only objection is that they need more careful tending.

The main points to be observed in forming mixed woods are that the soil and situation should (1) be such as will suit the kinds of trees intended to be mixed; (2) that the mixed crops should be such as can adequately protect the productivity by guarding the soil against loss of moisture through sunshine and

exhausting winds, and against becoming overgrown with weeds through too open a leaf-canopy overhead ; (3) that light-demanding trees should be of quicker growth in height than any shade-enduring kinds surrounding them, or should be specially favoured during thinnings ; and (4) that during all stages of growth each of the different trees intermixed should have sufficient individual growing-space to provide for the proper expansion of its crown of foliage and its root-system, and more especially when the several trees are approaching their maturity. The old British system of forming mixed woods geometrically according to a stencil-like "planter's diagram," or in alternate rows, &c., is not a sound system to go on, as it gives no consideration to changes occurring in the soil and the situation. These can only be properly taken into account when variations in the composition, depth, moisture, and other physical properties of the soil are noticed and provided for by judicious admixture of the various kinds of trees individually, or in small patches or groups of varying size, according to the circumstances of each case and the local market for timber of different kinds. A regular survey of the land to be planted should be made three or four years before planting begins, so as to estimate the number of plants of each kind wanted and provide them from the nursery. Such groups may vary from a small size up to many acres in extent.

CHAPTER II.

THE FORMATION, TENDING, AND RENEWAL OF WOODLAND
CROPS.

In forming Woodlands on waste lands, turf-bogs, poor hill-pastures, or arable land thrown out of cultivation, one must either sow seed or plant young live plants; and owing to the strong growth of weeds that takes place in our damp climate whenever such land is enclosed and the sheep and cattle are removed, **planting is the rule**, though acorns used to be dibbled in England long before planting began in the seventeenth century.

Plantations intended for timber-crops to be worked on business principles should be formed and managed upon some regular plan laying down the objects desired by the proprietor and the general scheme he has in view with regard to formation, tending, management, and ultimate harvesting; because timber-growing on any large scale can only, like other commercial enterprises, be conducted properly if prudent business methods be adopted. This does not mean that forecasts in any working-plan for forty or sixty years hence should, or could, be carried out just as intended by the present landowner; but later on it will always be useful to know the original intentions in forming and the measures taken in tending the plantations. With regard to the choice of trees for planting, the timber-crops most likely to prove profitable on land of poor quality are Conifers

(Scots Pine on dry sandy places, Austrian Pine on lime, Larch on fresh soil with good natural drainage, Silver and Douglas Firs on fresher land, and Spruces, Cypressess, and Red Cedar on moist soil). Broad-leaved trees require land of better quality (Oak on clay ; Beech on lime or chalk ; Oak, Ash, Elm, and other hardwoods on loams and mild fresh or moist soil ; and Poplars, Willows, Alders, and Birch where the land is wet, but not water-logged). The local market and demand for one or another kind of wood must influence the choice to a great extent ; but as a rule it is wisest to try to grow the kind of timber for the production of which the given soil and situation seem most suitable. And this, of course, means that wherever the soil and situation show marked differences, different kinds of trees should be planted, with the result that the plantations will become mixed woods formed of larger or smaller groups of trees suited to the given local conditions. These same considerations also mainly determine the amount of draining, clearing of surface-growth, soil-preparation, the best method of planting, and the number of plants per acre, and thereby practically fix the total cost of planting per acre.

But woodland planting of any sort can only be successful when there is a favourable combination of the following factors : (1) a suitable soil and situation, with such drainage and other soil - preparation as may be necessary ; (2) suitable kinds of trees for the given local conditions, and of a suitable size and quality ; (3) a suitable method of planting, and a sufficient number of plants per acre ; (4) adequate protection against human acts, live-stock, game, and vermin for some years, till the young plants have thoroughly established themselves ; and (5) immunity from serious damage by late frosts, drought, fire, insects, fungus disease, &c.

Drainage and Soil-preparation are in most cases necessary to a greater or less extent, both when planting new lands and when old woods are being regenerated either naturally or artificially ;

and this preparatory work may, according to circumstances, extend to the soil, the subsoil, and the surface-growth of weeds. Sour, wet, marshy, or water-logged lands, peats or clays, must first of all be drained to carry off the injurious excess of soil-moisture, and to allow of a freer circulation of oxygen within the soil; for wet, undrained land remains cold and inert. Bog-myrtle patches are always sour and acid, and need very thorough drainage and aeration before becoming plantable with profit; and where plenty of more suitable land is available, such patches should be excluded in the meantime.

In a wet climate like the West of Scotland a considerable amount of surface-draining will usually have to be done, merely to carry off the heavy rain-water falling during about nine months in every year. Throughout most of the extensive waste-lands in Scotland and Ireland there are large tracts with deep peaty and mossy soil resting on stiff clay or hard gravelly pan, preventing water percolating downwards; and to be effective drains should pierce through this, though the width, depth, and distance apart of the drains will depend on the wetness of the soil and the stiffness and depth of the impervious layer or subsoil. Another effect of drainage is practically to increase the depth to which tree-roots can descend for their food-supply. The deeper the drainage, the greater will be the permeability of the soil, and its capacity for being warmed by the sun and thus stimulated to provide plant-food.

When any extensive drainage system is necessary, as in preparing big peat-mosses for planting, a system of *main drains*, *side-drains*, and *feeders* should be dug, beginning at the lowest point. The main drains are usually about 3 to 4 ft. wide and $2\frac{1}{2}$ to 3 ft. deep, though often much wider and deeper on peat-bogs, and the small feeders are usually about a foot broad or more, and 10 to 12 inches deep, and the sides of all drains should be cut with sloping edges to prevent the sides falling in from top-pressure or scouring. The bottom of the drain should

even in the smallest feeders be at least 8 or 9 inches broad, so as to allow of their being easily cleaned out with a spade. According to the nature of the soil and the degree of wetness, drains may have to be dug from about 10 yards apart in stiff clay to 20 in light soil. They should, if possible, be dug a year or more in advance of planting, as peat-bogs and mossy lands subside considerably ; and they should be frequently inspected to see that they are not getting choked in any way. On deep moors it is better to drain them first of all to a depth of about 3 ft. to let the moor settle gradually and gain in density, than to sink trenches to their full depth at once. But even then it is necessary to open them for about one-third deeper than finally intended to be, in order to allow for subsidence. To drain at any time after planting is always risky, as even old woods may die through the subsequent diminution of soil-moisture and lowering of the water-level.

The cost of digging drains varies greatly with their size and the kind of soil ; but small drains usually come to about $\frac{1}{4}$ d. to $\frac{1}{2}$ d. a running yard, large side-drains $\frac{3}{4}$ d. to $1\frac{1}{2}$ d., and main drains $1\frac{1}{2}$ d. to 2d. a yard for ditches 36 by 30 by 9 in., and more, according to size. Where there are wet patches on hill-sides, the drains should run more or less horizontally along the foot of the slope down which the water comes, so as to intercept it at about a right angle and lead it off from the more or less level stretch ; and the more nearly horizontal each such catchment drain is, the greater is its effect as regards the land between it and the next drain lower down. On flat bogs or marshy land a rectangular network of drains is best. Where the land is practically flat and it is difficult to carry off the drainage water, or where moorpan or any stiff layer has to be broken through, and also when more or less parallel drains are being cut, the spoil earth should be thrown up in mounds well back from the trench or drain, and these can be used for mound-planting (say at 5 ft. by 3 ft. or 5 ft. by 4 ft. = 2904

or 2178 per acre) especially favourable when the land is wet (Fig. 1).

The Superficial Soil-preparation required will vary according to the soil-covering and the stiffness of the soil. So far as the soil-covering of weeds is concerned, the amount of clearing and preparation desirable before planting varies greatly, according to the amount of protection needed against late frosts and drought. Where these dangers do not exist a soil-covering like furze, broom, or bracken (all indicating a naturally well-drained soil) can be cut and burned; but otherwise it is best only to clear them sufficiently to give the young plants room to grow. Where the growth of bracken is very strong, it should

Fig. 1.

Drains 10 ft. apart; planting mound-lines 5 ft. apart.

be cut over twice or sometimes even thrice in the year before planting, the first switching being in June just as the fronds are uncurling. This exhausts the vigour of growth, and during the year of planting it may only be necessary to beat back the fronds in late summer, to prevent them overlying the young plants. Heather, whortleberry, and the like, which do not spread, whip, or choke the plants, are in most cases beneficial by sheltering the young plants against late frost, drying spring winds, early summer drought and scorching, and even against rabbits (if not numerous) and black-cock. Sporadic Birch or Aspen, too, ought then to be left standing for protection against frost and drought till the young plants have established themselves, when they can be cut and removed without doing much damage, and when the seedlings and stool-

shoots then springing up can be more easily kept in check than would be possible if they were cleared before planting.

If the land be stiff, the soil itself also needs preparation by being loosened to improve its physical condition and promote aeration. On the score of expense, this special soil-preparation is usually confined to opening up pits, either with C- or S-conical spades (as is cheapest), or with pick, pick-shaped hoe, or mattock (see page 68). When sand-dunes and shifting sands have to be planted, the preliminary preparation consists in fixing the sand by means of hurdles, turf, or tree-branches, before sowing or planting sand-grasses, everlasting pea (*Lathyrus*), Pines, &c.

Number of Plants needed, and their Supply.—It is best to examine the planting-ground about 3 or 4 years before planting to forecast the number of different kinds of plants that may be needed, and the amount of drainage and soil-preparation that may seem necessary. As it is best to form mixed plantations by planting in groups according to soil and situation, the land should be examined with a soil-testing boring-stick to ascertain its nature and depth; and with the information thus obtained one can forecast the number of plants actually needed when the planting-time arrives.

Say that 20 acres are to be planted, and that three acres seem most suitable for Larch, 3 for Douglas Fir, 4 for Red Cedar, 7 for Spruce, and 3 for Scots Pine, that planting is to be at 4 by 4 ft. (2722 per acre), and that 10 per cent extra may be needed for filling blanks, or 3000 per acre in all; then one knows that the supply of plants that must be raised in the home nursery, or else purchased, will be:—

Larch	$3000 \times 3 =$	9,000
Douglas Fir	$3000 \times 3 =$	9,000
Red Cedar	$3000 \times 4 =$	12,000
Spruce	$3000 \times 7 =$	21,000
Scots Pine	$3000 \times 3 =$	9,000

Total plants for 20 acres = 60,000

Nurseries.—If large numbers of plants are annually needed for regular planting, a *permanent home nursery* is profitable, besides providing thoroughly acclimatised plants. Otherwise plants have to be purchased from nurserymen, in which case it is best to buy them as 2-year seedlings and acclimatise them in a *temporary nursery* on part of or near the planting-ground. Set here at 1 foot apart (43,560 per acre), only $\frac{1}{16}$ of the land needs at first to be enclosed and planted; and when they are of the size desired, $\frac{15}{16}$ of them can be lifted and planted out, leaving the remainder at 4 by 4 ft., the pitting being done very cheaply with a C- or S-conical spade. This method acclimatises the plants; means the least possible cost in transport; 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 loss of plants; and is cheapest, as even fencing is reduced to a minimum.

Nursery Work is of great importance, because the success of planting depends as much on well-developed and healthy plants as upon a rational method of planting and a proper choice of the kinds of trees suitable for the soil and situation. The following are the main points to be kept in view in making and working a nursery :—

1. A nursery should be on an open and airy but not exposed situation, avoiding hollows and damp frosty spots, where insects and fungi are also apt to abound. A northerly aspect is preferable to a hot southern exposure, or to the east, where damage from late and early frosts and drying spring winds is greatest—for least damage is done, after a frosty night, when the air is gradually warmed before direct sunshine falls on the plants. It should be well fenced against rabbits, &c., and should have a good water-supply in case of drought.

2. A well-drained, good sandy loam is the best soil, and it should not be in rich cultivation, else the plants grow lanky and not bushy and robust for planting on rough hillsides with poor soil.

3. A square or rectangular nursery can be most conveniently divided into rectangular plots and beds, and its size depends on the number, age,

and kinds of plants to be grown for annual output. One acre of nursery will provide seed-beds and transplant lines for an annual output of about 66,000 2-year-2 plants, or enough to plant 22 acres at 4×4 feet (2722 per acre) and give 10 per cent for filling blanks. If 2-year Conifer seedlings only are required, then from $\frac{1}{2}$ to 1 per cent of the area to be planted annually will suffice; while if 2-year-1 and 2-year-2 transplants are needed, then from 4 to 5 per cent of the annual area may be wanted for the nursery (to allow of fallowing and green-manuring about one-fourth annually).

4. For a new nursery, after any draining and levelling needed, the ground should be trenched for 18 inches or more in depth, and the soil well broken up and pulverised; and by putting the surface-soil at the bottom of the trench, expensive weeding is reduced to a minimum. Where the soil is only 6 or 8 inches deep, it should be ploughed as deep as possible, with a skim-coulter on the plough to skim off the surface layer about two inches deep and turn it over into the bottom of the previous furrow. This makes the turf easier dealt with when the plants are being laid, though it neither obviates trouble when digging with spades nor prevents growth of weeds.

5. Towards the end of April or early in May is soon enough to sow most kinds of seed upon seed-beds whose soil has been thoroughly pulverised at least down to one spade's depth by repeated digging and raking; and the seed should be sown when the soil is quite friable and neither wet nor dry. But seed of low germinative power should be sown as soon as it ripens (Elm in June, and Birch in July or August).

6. It is important to get good seed from healthy, middle-aged trees, and its germinating power should be tested (with wet flannel or other test) experimentally in advance, to know whether to sow thickly or thinly on the seed-beds.

7. The seed-beds should be about 3 ft. 9 in., or not over 4 ft. broad—though 3 ft. 9 in. is preferable, to permit of easy weeding without tramping and injuring the plants. Seeds are sown in drills or broadcast if very small (Birch, Alder, Elm, &c.), while large seeds like acorns and chestnuts are dibbled or sown singly. In sowing broadcast, after the seed-beds have been lined off to a suitable length (25 ft.) and breadth, part of the surface-soil is drawn with a fine iron rake to each side of the bed, and a light roller is used to smooth the surface; then the seed, previously moistened and rolled in red-lead powder to protect it against birds, mice, and insects, is broadcast evenly over the bed, lightly covered with the drawn soil by quickly raking over the bed, and pressed in by the roller being again lightly passed over the surface. The soil-covering need only be from $\frac{1}{4}$ to $\frac{1}{2}$ inch deep, a light, dry soil needing the thicker covering to prevent the seedlings getting scorched during hot, dry weather or being lifted by frost.

8. The quantity of seed required may vary (according to the ascertained germinative percentage) from $\frac{3}{4}$ to 1 lb. for Scots Pine and Spruce, about or over $1\frac{1}{4}$ lb. for Larch, and about 2 lb. for Silver Fir per 100 sq. ft. of seed-bed for broadcast sowing; but this will of course vary according to the quality of the seed. This usually gives per 100 sq. ft. of seed-bed from 5-6000 2-year seedlings of Larch and 8-10,000 of Scots Pine fit to line out. Drill-sowing by hand takes longer than broadcast sowing, but weeding is easier and cheaper, less seed is needed per 100 sq. ft. of seed-bed, and the seedlings are less likely to be lifted by frost.

9. If drill-sown *thickly*, Conifer 1-year seedlings have to be transplanted, but if *thinly* drilled or sown broadcast, they can stand 2 years before being put in the nursery lines at distances suited to the plants and the time they have to stand there (lines usually 12 in. apart). But Douglas Fir and Menzies Spruce often do best when planted out after the 1- or 2-year-old seedlings have stood for only one year in the lines. Transplanting for 1 or 2 years develops strong, sturdy, well-rooted plants, suitable for establishing themselves on rough ground with poor soil. In transplanting, it is best to range seedlings in beds according to their size, so that all on one bed may develop about equally and be ready for planting out at the same time. And when transplanting, long straggling roots should be pruned back (fig. 2), as likely to get doubled and deformed in the trench. Thus the bigger class of seedlings may perhaps be ready for putting out as 2-year-1 transplants, while the smaller may only be ready as 2-year-2 (or else 2-year-2 and 2-year-3 in Scotland). These weaklings are very useful for filling blanks in young plantations.

Fig. 2.
Pruning shears.

10. Where extra strong plants are specially wanted, they can best be obtained by transplanting annually for 2 or 3 times, to stimulate growth of rootlets near the stem (this being a natural effort to speedily overcome the physiological disturbance caused by loss of rootlets and root-hairs at the extremities when transplanting).

11. The work of transplanting seedlings into nursery lines costs from 3d. to 5d. per 1000, but weeding costs a good deal from time to time, and so transplants usually cost from 6s. to 8s. per 1000, according to the price of the seed and its quality, and the amount of weeding needed.

12. In every permanent nursery a spare plot should be kept in hand for a year to rest and improve it. This can either be manured and put under a crop of potatoes, turnips, vegetables (or mustard, if there is any danger from wire-worms), or else lucerne may be grown and dug in during autumn to decompose into a mild green-manure. On a sandy soil lupin

is specially useful (owing to the fixed nitrogen in the root-nodules). About $\frac{1}{2}$ to $\frac{1}{4}$ of the nursery area should be treated thus each year; and if direct manuring be applied at all, it is best given in the shape of good leaf-mould (beech best, if available) or well-rotted turf, &c. These mild natural manures are generally preferable to stronger artificial manures, which usually tend to produce lanky plants unsuitable for planting out on rough, poor land.

13. Drill-sown beds need less seed, are easier and cheaper to weed, and less liable to have the young plants lifted by frost (a danger greatest on stiff soil); and weeding is facilitated if the drills are made across the bed, and not longways. Acorns can be dibbled 2 in. apart in drills about 9 in. apart and covered with about $1\frac{1}{4}$ in. of soil; but beech-nuts and similar seeds can be put much closer in 6-in. drills; and small seeds like those of many Conifers are sown in 6-in. drills more thickly, and are far more lightly covered with earth. Sowing should take place in dry weather, if possible; and after the earthing-over of the drills, the beds should be lightly rolled. Scots Pine, Spruce, and Larch seed sown broadcast should be raked over and rolled; but very small seeds (Alder, Birch, Red Cedar, Cypressess, &c.) need only be firmed in with very little soil-covering. For dibbled seed the quantity required for each bed can easily be calculated; but for drill-sowing of smaller seeds the following are rough general averages of the quantity needed per 100 sq. ft. of seed-bed: Scots Pine, Spruce, Elm, and Hornbeam, about 4 oz.; Austrian Pine, Ash, Maple, and Sycamore, about 6 oz.; Larch, Douglas Fir, Birch, and Alder, about 8 oz.; Silver Fir, about 1 lb.; and for broadcast sowing from 2 to 3 times these quantities are needed. The period of germination varies from 2-3 up to 4-6 weeks for the different kinds of tree-seeds. (See also page 38.)

The following are data for 1909-10 from an Argyllshire nursery on a stiff soil apt to lift with frost, the seed-beds being made 25 ft. $\times$ 4 ft. = 100 sq. ft., and 10 drills sown thickly $4\frac{1}{2}$ in. apart:—

Seed used per 100 sq. ft. lb.	Kind of Tree.	1-year Seedlings.	1-year Seedlings per 1 lb. of Seed.
$1\frac{1}{2}$	Scots Pine (Strathspey)	55,000	37,000
$2\frac{1}{4}$	Corsican Pine	19,000	8,400
$4\frac{1}{2}$	Spruce	130,000	29,000
$2\frac{1}{4}$	Douglas Fir	22,500	10,000

The $2\frac{1}{4}$ lb. of Douglas Fir cost 30s., and past experience shows that the 22,500 1-year seedlings will give fully 15,000 (and probably 18,000) plants fit for planting out, at the following actual cost:—

	s.	d.
1st year: preparing, sowing, and 3 hand-weedings for 22,500 plants	2	8
2nd year: transplanting, 15s.; and 4 weedings, 6s. 8d.	21	8
3rd year: 3 weedings	5	0
<hr/>		
Total cost for 22,500, less 30 per cent for casualties =15,000 1-year-2 transplants	29	4
<hr/>		
or say	30	0
Add cost of seed	30	0
<hr/>		
Total cost of the 15,000 plants	60	0
<hr/>		

This, excluding rent, &c., of ground and general share of supervision, is equal to 4s. per 1000, although the cost of seed was high.

On the Continent two or more short cross-drills are usually made at once with a *drillmaker*, consisting of a thick board as long as the bed is broad ($3\frac{3}{4}$ or 4 ft.), with projecting battens (of the size and depth the drill is to be) screwed on to it at one-fourth the width of the board from each side. Say the breadth of the beds is 4 ft., and the drills are to be 7 in. apart, the board would be 14 in. broad (fig. 3), and the projecting pieces of wood (say $\frac{1}{2}$ in. deep and $\frac{3}{4}$ in. broad) would be fixed at $3\frac{1}{2}$ in. from

each edge, leaving a space of 7 in. between. Each time the board is moved forward on the bed, the $3\frac{1}{2}$ in. left at one side where the board has already been pressed down, and the $3\frac{1}{2}$ in. on the other side when it is placed in the next position, make up the 7 in. from drill to drill. As the drill formed has the shape , the seed poured in falls to right and left, and thus gets better distributed. Or 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 $\frac{3}{4}$ or 1 in. board. Various mechanical contrivances are used to ensure a more equal distribution of seed in the drills than by hand-sowing.

One of the simplest is a *seed-distributor* (fig. 4), made the same length as the drillmaker, and used along with it. This consists of a piece of wood (*a*) as long as the seed-bed is wide ($3\frac{3}{4}$ or 4 feet), with a longitudinal groove (*c*) wide and deep enough to hold the quantity of seed to sow. The seed is kept in place by a sliding top-piece (*b*), and the whole is turned round and placed exactly over the drill; and on the top-piece (now resting on the ground) being withdrawn, the seed falls into the drill. Another simple contrivance is the *sowing-horn*, made of tin (fig. 5),

Fig. 5.

Fig. 4.

Cross-section of a seed-distributor.

a. The grooved piece of wood; *b.* The sliding top-piece; *c.* The groove for holding the seed.

The Sowing-horn.

Fig. 6.

Acorn-dibbler.

chiefly used for small Conifer seeds. On its spout are four movable nozzles to regulate the issue of seed. An *acorn dibbler* can also be used for dibbling large seeds (fig. 6).

In Britain, seedlings are usually set in the transplant lines by being placed in position against the perpendicular side of the trench cut to receive them; and after the loose earth is replaced, it is trodden in. This tends to deform the roots. A better method is to use a seedling-pricker (fig. 7), notched so that the seedlings can be put at the required distance. When charged with plants, it is laid along the edge of

the trench, and the earth filled in and gently firmed before removing *b* and withdrawing backwards the main piece *a*, *c*, *d*.

Plants can also be raised by *layering* a branch of a tree and partially burying it in the soil till it roots itself and can be severed (as is sometimes done with Lime and English Elm), or by planting *cuts* or *slips* taken from a branch (as is often done with Willows and Poplars). But these methods are mostly employed to propagate varieties for ornamental purposes.

Nursery Pests.—The best general protection against *birds*, *insects*, and *mice*, is to moisten the seed and roll it in red-lead powder before sowing. But if numerous, *mice* can only be got rid of by laying poisoned wheat in drain-tiles. *Squirrels* have to be shot. *Rabbits* have to be kept out by 1-inch mesh wire-netting 4 ft. wide bent outwards for 6 in. below the ground, and for 6 in. at top, to prevent burrowing and climbing over. For *roe-deer* an extra strand of wire is needed, to raise the fence to about 5 ft. high. *Insects* are best kept down by hanging up cheap wooden nesting-boxes for starlings and other insectivorous birds; but *cockchafer-grubs* and *mole-crickets* have to be dug up. If *wire-worms* are bad, sowing mustard on infested parts is the best means of exterminating them. For *slugs*, grease traps should be laid down and visited every

Fig. 7.

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.

morning. *Fungus diseases* can usually be checked by spraying with paraffin emulsion or Bordeaux mixture ; but if this seems ineffective, the diseased plants should be pulled up and burned. Both *frost* and *scorching* can best be prevented by placing light movable screens over the beds needing protection. Such screens may be of coarse canvas or sacking running with rings along wires raised on wooden pegs, or wooden lattice-work frames, or tree-branches ; but if Conifer tree-branches be used over Conifer-beds fungus disease is likely to break out, through saprophytic fungi on the dead foliage becoming parasitic on the seed-beds or in the transplant lines.

Package, Transport, and Storage of Plants.—Seedlings can easily be moved to the nursery-lines in hand-baskets ; but when either seedlings or transplants have to be sent to some distance, they should be properly protected against heat and wind, to prevent the drying-up of their rootlets. On being carefully lifted from the beds, they should be tied in bunches of fifty, and packed with damp moss in bundles of convenient size. To prevent heating, evergreen Conifers should be packed with the leaves of one bunch touching the roots of another, and in dry weather the moss should be moistened from time to time. If the plants have to be taken by cart, a covered cart best protects the plants from sun and wind. From a home-nursery only so many plants will be sent daily as can be planted. But if received in bulk from a distance they should at once be unpacked, moistened if necessary, and *sheughed* or heeled in by being bedded in shallow trenches in some cool, shady, sheltered place till wanted for planting.

Best Season for Planting.—Whether spring or autumn planting is best, often mainly depends on the extent to be planted annually and on the amount of labour obtainable locally, although, other things being equal, it is usually best to plant broad-leaved trees in autumn and Conifers in spring. Under any circumstances the moving of plants from one place

to another creates a physiological disturbance, the power of overcoming which varies in different kinds of trees. Healthy plants may with care be transplanted at any time of the year; but physiological disturbance in the organism is reduced to its minimum if the removal take place either just after active vegetation has ceased in autumn, or just before it recommences in spring. But as root-growth goes on to a slight extent in broad-leaved plants during the winter period of rest, autumn planting is (other things being equal) best for broad-leaved kinds, and spring planting for the evergreen Conifers to save them from being shaken by wind in winter. Wherever the supply of suitable labour is limited, however, planting work over any extensive area practically goes on right through from autumn till spring whenever the weather is open and favourable. In spring-planting it is best to plant the warmer exposures before the colder hollows and northern aspects, and to plant first of all the kinds which flush their foliage earliest (Birch, Elm, Chestnut, Larch), then to set out the other deciduous trees, and to plant the evergreen Conifers last of all, as they mostly stand transplanting well even after their new foliage begins to flush (not Austrian Pine, however, which generally transplants badly, though sometimes best in July if that be a wet month). Douglas Fir seems to do best when planted late in April. If possible, planting should be done in mild open weather, and not during heavy rain or frost; and great attention should be paid to keeping the plants well protected, in a planter's tray filled with wet moss and having two flannel flaps covering the top, to prevent drying up of the rootlets and root-hairs.

The Best Distance in Planting.—The poorer the land, the closer should the plants be set; and the better the land, the sooner the plantations will establish themselves and grow up to form a thicket from which thinnings may be profitable. But the best distance for planting, or the number of plants needed

per acre, depends both on the soil and the kind of tree, and also on the prospect there is of being able to dispose profitably of young thinnings. Wide planting usually means expensive cleaning and weeding in young plantations; but there is no use in incurring the heavier expense of close planting if a somewhat wider distance will practically answer equally well, unless a good local market for early thinnings promises a fair return. The best distance, therefore, depends to a great extent upon the size of the plants used; and this again depends on the nature of the soil and the situation. As a rule, it is best to use 2-year-2 plants and to set them about 4×4 ft. apart (2722 per acre). This may be taken as the average distance for "pitting" or "holing," as it allows the plantations to grow up to from fifteen to twenty years without a first thinning being needed. But where two-year seedlings can be dibbled or notched on light soil, the cheapest form of planting, they can be put in at about $3\frac{1}{2} \times 3\frac{1}{2}$ ft. (3556 per acre), or on a very poor soil and an exposed situation at 3×3 ft. (4840). Unnecessarily close planting, besides being dearer, also tends to draw up the young stems in a too crowded condition and makes early thinning imperative, perhaps before there is any market for small material; while wide planting tends to make the young poles branching and rough until they form close canopy. Hence the probability of successful growth, the cost of planting, and the probable profit from early thinnings are all important points to be considered in fixing the planting distance. Shade-enduring trees can be planted closest; but among these the Douglas Fir, owing to its rapid growth at first, need not be planted closer than $4\frac{1}{2} \times 4\frac{1}{2}$ ft. (2151 per acre) or even 5×5 ft. (1742 per acre), unless there is a good market for young thinnings. For a very light or sandy soil, dibbling and notching at 3 or $3\frac{1}{2}$ ft. are certainly the quickest and cheapest methods of planting; but on stiffish land, "hole-and-plug" planting with a C-conical spade, or pit-planting at about 4 ft., either with ball-plants

raised from the nursery with C-conical spades or with naked plants, is more likely to prove successful, though costing more.

The Number of Plants needed per Acre can easily be calculated for planting at equal distances in lines (in squares or rectangles), by multiplying the distances into each other to give the average growing-space and dividing the 43,560 sq. ft. in an acre by this. But if planting be done in equilateral triangles as sometimes happens (especially in windy places and shelter-belts), then the number of plants needed for squares or rectangular lines has to be multiplied by 1.155—*i.e.*, about one-sixth more has to be added.

Distance from Plant to Plant. Feet.	Number of Plants needed per Acre for Planting.	
	In Squares.	In Equilateral Triangles.
3	4840	5590
3½	3556	4107
4	2722	3143
4½	2151	2484
5	1742	2012

But in practice mathematical regularity is neither possible nor desirable, and on broken or stony ground the plants have just to be put in where there are suitable pockets of soil. Planting in squares or lines (*e.g.*, at 4 × 4 ft., or 5 × 4 ft.) is easier, though triangular planting best utilises the growing-spaces.

The Different Methods of Planting.—One of the great advantages of planting over sowing is that wherever any special soil-preparation has to take place, as is always the case except in dibbling or notching, it confines this to the lowest limit. Thus if large pits of 12 in. square have to be opened 4 ft. apart from centre to centre, this only means specially preparing 2722 sq. ft., or one-sixteenth of each acre, whereas strips prepared for sowing, even if made wide apart, represent a much larger

proportion. Planting may take place either with naked seedlings, usually taken from the seed-beds at two years of age, or with older transplants, usually 2-year-2, taken from the nursery lines either naked or with balls of earth attached to their roots. In planting with two-year seedlings the plants are generally notched or slit-planted, while plants with balls of earth are usually pitted or mound-planted. The rougher the ground and the greater the danger from weeds, the stronger and more robust should be the plants used; but good 2-year-2 transplants are on the whole the best to use. It is best to plant the young plants singly, as wisps of three or four seedlings or young transplants seldom grow well. When planted, neither seedlings nor transplants should stand deeper in the soil than they have stood in the nursery, unless taken from a nursery with stiffish soil and planted on very light friable soil, when slightly deeper planting diminishes danger from drought. Deep planting is bad for all kinds of plants, but especially for Conifers, and among Conifers especially for the shallow-rooting Spruce, which then endeavours to throw out a new lateral root-system nearer the surface. If planted too deep on a friable sandy soil, the plants may in a short time be able to adjust themselves to their new environment; but if the soil be so stiff as to prevent free aeration, then the root-system gradually gets suffocated from want of oxygen. And if in lifting the plants from the nursery lines many of the rootlets get damaged, then it is desirable to trim the foliage slightly with the pruning-shears, to try and restore something like the previously existing normal balance between imbibition and transpiration. Such trimming should, however, be avoided so far as possible; hence the use of small plants and simple planting methods is preferable to larger plants and costlier methods of planting, if the latter are not rendered necessary owing to strong growth of weeds or other reason. Wherever obtainable, the shelter of woods and plantations should be taken advantage of when drawing up a scheme of

planting extensively, as young plantations always thrive best when screened from strong winds. On old arable land the planting of Scots Pine is apt to induce root-disease; and on poor soil, especially if limy, an admixture of White Alder is often beneficial through the supplies of humus obtained from its cast foliage, and through its power of throwing up root-suckers plentifully. Quick-growing or hardy kinds of trees, like Larch, Pine, Rowan, and Birch, are sometimes planted as *nurses* to protect less hardy but more valuable kinds from frost; but the nurses should be cut out as soon as they have served their purpose, otherwise they suppress the trees they were intended to assist, and grow up into a poor, thin, unprofitable wood, perhaps not bearing half the crop it might have yielded.

The usual methods of planting are—

1. NOTCHING OR SLIT-PLANTING, usually at 3 or $3\frac{1}{2}$ ft. apart (4840 or 3556 per acre)—
 - (1) CUSTOMARY BRITISH NOTCHING, with the ditching-spade or similar tool.
 - (2) VERTICAL NOTCHING, with a flat-faced, iron-shod dibble, ditching-spade, or similar tool (*e.g.*, Mansfield spade, a ditching-spade with horizontal treads at top).
2. PITTING, usually at 4 ft. apart (2722 per acre)—
 - (1) CUSTOMARY BRITISH PITTING, with pick, pick-hoe, or mattock.
 - (2) PITTING WITH A C- OR S- CONICAL OR A CYLINDRICAL SPADE.
3. MOUND-PLANTING, in rows upon mounds thrown up from ditches or heaps of earth on wet soil.

Naked plants are generally used in Britain, but plants with conical or cylindrical balls of earth round their roots can be lifted from any not too light soil by using the C-conical or the cylindrical spade, and transplanted into pits made on the planting ground by similar tools of the same size (Fig. 12, p. 69).

1. **Notching or slit-planting** of any description is only suitable for a very light sandy or friable soil, in which the roots

can spread easily after being jammed in ; and even then vertical notching with a broad-faced dibble is by far the preferable method, for though the roots are pancaked, they can hang down in their natural position and are less likely to be bent and become badly malformed than in the customary method of notching. For a stiff clayey or peaty soil, notching of any

Fig. 8.

• Place where plant is inserted.

Notching with 2 cuts (1, 2).

Double-notching with 3 cuts (1, 2, 3).

sort is a most unreasonable way of trying to raise really good and healthy plantations.

The customary British method of notching (Fig. 8) is to make either two deep rectangular cuts into the soil (L or T) or else

three cuts (*double-notching*, H or X); and as the last cut is made, the handle of the ditching-spade, or similar tool used, is bent down to near the ground while a plant is slipped in where the opening is largest ; then the handle is raised again, the spade withdrawn, and the sod firmed by tramping. Its

Fig. 9.

only attraction is its cheapness ; and any other method (*e.g.* dibbling) suitable for a light soil with sufficient depth seems to be preferable even if it may perhaps cost slightly more.

Such a method can only succeed on a very light sandy soil, and even then the roots are cramped into an unnatural position, differing greatly (Fig. 9) from the more vertical position they should occupy in nursery-lines producing good plants. Even in light, sandy soil the roots show distinct traces of deformity for many years, and on stiff loams and clays it is hardly rational to expect healthy and profitable plantations, because the roots often look as if they had been dipped into a glue-pot before being planted. From a scientific point of view, notching is a bad system of planting on any except a very light soil ; yet

it is only fair to say that many of the old Larch plantations on hillsides grew well and were profitable. But root-deformity is very prevalent among notched plantations; and this must lead to physiological disturbance, making the young plants less hardy against frost, and increasing danger from insects and fungi. That fungus disease is often seen in young notched Conifer plantations is probably partly due to bark-wounds made by the planter when treading the sods to firm the young plant. If sods be turned and notched through, this checks the growth of weeds for the next two years (practised at Inverary about fifty years ago).

Vertical notching, whether done with a flat-faced dibble, or with a ditching-spade or any other similar tool, is carried out upon similar lines. The flat-faced

dibble (Fig. 10) is simply a bit of wood with a short curved handle and an iron-shod tip, about 3 to 4 in. broad at the top, and tapering to a point. The first insertion (a) into the soil is vertical, into which the plant is inserted deeply, shaken lightly, and then pulled up to its proper position, to prevent the roots getting bent; the

Fig. 10.

The iron-shod Dibble for vertical notching.

next, about 2 in. away from the first, is slanting, (b), and pressed forward from b to a to fix the plant already brought into place. A small third insertion (c) is made and pressed forward to close up the slit at b. The whole work can be easily done by one man, woman, or child. An extremely cheap method, it has the great advantage over notching of ensuring the roots having a natural and more or less vertical position. But even in light soil the roots are pancaked, and have to overcome a good deal of physiological disturbance before the plant establishes itself and regains a normal root-system.

Another cheap method, which may possibly answer well on a somewhat stiffer or a peaty soil, is the *hole-and-plug* planting with a C-conical spade, a man making the holes and lifting the conical plug entire, and a boy inserting the plant at its proper level with his left hand and replacing the plug with his right, then carefully treading the plug down.

But this will also pancake the root-system, though to a somewhat less extent than in dibbling.

2. **Pitting** consists in opening out square or round holes at 4 ft. apart, or other planting distance, the pit being opened either with a pick and spade, or hoe-pick, or mattock in very stiff, stony, or gravelly ground, or with a C- or S-conical or a cylindrical spade on any kind of land (loam, peat, &c.) permitting of its use. The pits are generally dug about 9 to 12 in. broad and deep, their cost, of course, increasing with the size. But on suitable soil the use of conical or cylindrical spades is much quicker and cheaper, though not making the soil so friable. And especial advantage is gained by using a strong, heavy (10 to 11 lb.) steel S-conical spade (Fig. 11), which breaks up the soil instead of lifting a solid plug as the C-conical and cylindrical spades do, though these can be

S-conical Spade.

- ab. Long wooden handle.
- c. Iron shaft.
- d. S-shaped conical blade.
- e. The hole prepared on spade being forced into soil and turned round from a to b.

used both for opening pits and lifting ball plants (Fig. 12), as might often be done from temporary nurseries near the planting-ground. The best size for conical spades is 6 in. in diameter and 10 in. long, and they should be heavy (10 to 11 lb.) for a stiffish soil. In a dry climate it is best to open the pits in autumn and plant in spring, as the soil gets improved

by the action of frost; but where the winter rainfall is heavy and more or less continuous, it is better to open them at time of planting. And when wet hillsides have to be planted, a shallow surface-drainage can be obtained by lifting in autumn thick sods of turf of about 18 in. square in continuous lines from below upwards, inverting the sods at the planting spots (clearing away heather at these spots) to let the grassy surfaces

Fig. 12.

Pitting with Cylindrical or Semicircular Spades, and plants with balls of earth.

a, Plant as lifted from nursery-bed; *b*, Pit made for it on planting ground.

bite into each other, and tramping them well down; then in spring pits can be opened through these upturned sods with a heavy 6 in. diameter S-conical spade and the plants put in. This combination of pitting and mound-planting both helps to drain the land and raises the plant above the water-level, with a double depth of the top layer of soil (see footnote, p. 73). On stiff or peaty soil an addition of sand or small gravel is very useful in the pit.

In planting in such pits it is best to take a good handful of soil, squeeze it well and stick it on the lip of the pit, then put the plant against this in proper position, when both hands will be free to fill the soil into the pit and firm it properly about the roots. Or a small mound of soil is formed by hand at the bottom of the pit, so as to bring the plant into proper position,

and the roots are spread carefully over this mound and the rest of the soil filled in and firmed (Fig. 13).

Fig. 13.

For the heavy spade-work men are of course needed ; but the actual planting is both cheaper and also far better done by women, boys, and girls, than by men.

On very rocky ground planting in the pockets of soil with a *strong hand-trowel* might often be a good way of pit-planting.

3. **Mound-planting** in wet places consists in raising small mounds of earth and planting on the top of these, in whatever

way (dibbling, pitting, &c.) seems advisable (Figs. 14 to 17).

Fig. 14.

Ordinary Mound-planting with naked plants.

Fig. 15.

Combination of Pitting and Mound-planting with naked plants.

Fig. 16.

Combination of Pitting and Mound-planting with ball-plants.

Fig. 17.

Combination of Notching and Mound-planting with naked plants.

On wet land that has to be drained before planting, it is best to throw the spoil-earth well back from the ditches and use it for mound-planting.

Thus, if the ditches are 10 ft. apart, and the spoil-earth be thrown out to $2\frac{1}{2}$ ft. on each side of the ditch, this will give mounds 5 ft. apart, upon which the plants can be set at 3, or $3\frac{1}{2}$, or 4 ft. apart (2904, 2489, or 2178 per acre).

Regularity in planting is not possible on very stony ground, or wherever pockets of earth have to be used; but it is best to have a gang of planters headed by an experienced foreman, (1), who either plants along a line marked out with a tagged rope or has a 4 ft. stick to

Planting in lines, each planter, 2, 3, 4, taking his line from the foreman, 1.

measure off the distance with, and who starts first, while the others, (2) to (4), take their respective lines from him, at 4 ft. apart, or whatever the planting-distance may be (Fig. 18).

The Rate and the Cost of Planting vary greatly according to

local conditions as to soil, situation, labour, the size of the plants used, the planting-distance, and the method of planting. And, of course, draining and other soil-preparation may greatly increase the first cost, while the filling of blanks in the first two or three years after planting may add considerably to the total cost before any plantation thoroughly establishes itself. But *notching* and *dibbling* are certainly the cheapest methods, though only suitable for a very light soil, while *pitting* with pick or hoe is the most expensive, and especially on stiff and stony ground. *Pitting with conical spades* stands midway between these two extremes, though extensive data are not yet available, as this method is only now coming into use in Britain.

In the mild, open, wet climate of western Argyllshire a good planter can usually *notch* from 80 to 130 plants an hour, according to the nature of the soil, or on the average about 100 plants an hour, and gets 4d. an hour (3s. 4d. per day of 10 hours, or £1 a week); and a man and a boy ($2\frac{1}{2}$ d. an hour, 2s. a day) can generally average about 180 plants an hour. This means that during a ten-hour day a man can notch about 1000 plants, or will take about $3\frac{1}{2}$ ten-hour days, costing 11s. 8d. per acre at $3\frac{1}{2}$ ft. (3556 plants), or very nearly 5 days, and costing about 16s. per acre at 3 ft. (4840 plants); while a man and a boy notching 1800 plants in a 10-hour day, costing 5s. 4d., will do an acre at $3\frac{1}{2}$ ft. in 2 days, costing 10s. 8d., and at 3 ft. in $2\frac{3}{4}$ days, costing 14s. 4d. per acre. And taking 8s. per 1000 as the cost of good 1-year-2 or 2-year-2 transplants raised in a home-nursery—though from 6s. to 7s. will generally more than cover the actual cost per 1000, even when the seed is dear—this means respectively 28s. 6d. and 38s. 9d. for the plants, making the total first cost only about 40s. per acre at $3\frac{1}{2}$ ft., and from about 40s. to 50s. at 3 ft.—though if 2-year seedlings can be used the cost of home-plants will be greatly reduced. As a general average 35s. to 45s. an acre is about the first cost, and

subsequent beating up of blanks during the next two years usually brings the total cost up to 45s. to 55s. an acre.

The rate and the cost of pitting vary also considerably. The cheapest pitting with pick and spade known to me is that done on an Argyllshire estate in 1908-09, when pits 4 ft. apart and 9 inches broad and deep were opened in autumn at the rate of 800 a-day by a man at 3s. 4d., equal to 4s. 2d. per 1000, or about 11s. 4d. per acre. The cost of planting was found to be about the double of that, or 22s. 8d. per acre; and taking the cost of plants at about 7s. 6d. a 1000 from the home-nursery, this adds 20s. 6d. for plants, and makes the total first cost about 55s. an acre, exclusive of beating up blanks subsequently. This is, however, an exceptionally low cost with exceptionally small pits, and in general pitting usually costs from £3 to £4 an acre, though this may, on suitable soil, be reduced by using the C- or the S-conical spade.¹

Thus soil-preparation, planting, beating up and weeding during the first two or three years after planting may be roughly estimated as now costing about £3 to £4 an acre for *notching*, and from £4 to £6 for *pitting*, according to the amount of drainage and preliminary bracken-cutting, &c., needed, the size of plants and

¹ Two very interesting and instructive accounts, well illustrated, of Sir John Stirling-Maxwell's moorland pit-planting (with the Belgian form of the C-conical spade) through inverted turves at Corroul (Inverness-shire) will be found in the *Roy. Scot. Arbor. Socy. Trans.* for 1907 and 1910 (vol. xx., p. 4, and vol. xxiii., p. 153).—Shallow surface-drains 12 ft. apart were cut 24 in. wide at top, 15 in. at bottom, and 10 in. deep; and the peat-turf thus loosened was cut into 20-in. lengths, and the 24-in. by 20-in. sods removed, inverted, and laid regularly over the area at 3 ft. apart (4840 per acre). This soil-preparation—cutting turf-drains, and lifting and placing the turves in autumn, and boring pits through them with a 6-in. C-conical spade in spring—cost 46s. 8d. per acre, while planting (with sand and compost added in the pit) cost 16s. 8d., making 63s. 4d. per acre, excluding the cost of the plants, “which were for the most part 2-year seedlings from the home nursery, and their cost, though it cannot be exactly estimated, is very small.”

number per acre, the local climate, and the ability and training of the local labour supply. But the Report of the Royal Commission on Afforestation (1909) estimated the total cost of planting at about £6 an acre on the average.

Sea-Coast Planting invariably needs shelter-belts, as the wind and the spray damage badly the windward side of plantations. Beech, Sycamore, Elm, Ash, White Willow, Alder, and shrubs like Elder and Sea-buckthorn, stand sea-breezes well where the soil is loamy; but on sandy soil, Corsican, Austrian, Scots, Maritime, and Banks' Pines, and White Spruce, are among the best kinds for giving shelter. To be effective, shelter-belts must be at least 20 to 30 yards broad; and triangular planting is better than planting in squares. On the Holkham Hills, in Norfolk, an old rabbit warren on the sea-coast, the sand, after being fixed with bents and sand-grasses (*Arundo*, *Elymus*, *Carex*), was enclosed and planted with $\frac{1}{2}$ Corsican Pine, $\frac{1}{4}$ Austrian Pine, $\frac{1}{5}$ Scots Pine, and $\frac{1}{20}$ Maritime Pine; and these plantations have succeeded well. On the Continent large plantations on sand-dunes have been made, after fixing the outer sand by means of hurdles, by planting or sowing Banks' and Scots Pines. The success of the plantations is greatly assisted by sowing perennial lupin (*Lupinus polyphyllus*) or Everlasting Pea (*Lathyrus sylvestris*), owing to their nitrogen-fixing root-nodules and the good humus they yield.

The Tending of Woodlands consists in (1) the *weeding* of young plantations, and of thickets naturally regenerated, in order to enable them to establish themselves in the form desired; (2) the *thinning* of pole-woods and middle-aged crops; and (3) the *partial clearance of maturing woods*, in order to stimulate increment on the stems.

Plantations seldom succeed in establishing themselves without needing a certain amount of *beating up* to fill blanks caused by late frosts, &c.; and when old rough pasture land on hillsides has been enclosed and planted after the sheep are taken off,

there is usually (and especially in the damp climate of the western Scottish Highlands) a very strong and rank growth of coarse grasses and other weeds, which necessitate several *weedings* during the first two or three years, till the young plants get their leading-shoot up well above the danger of being smothered and overlaid by the grass; and besides freeing the tops of the plants from strong growth of grasses and other weeds threatening to overlay and suffocate them, softwoods like Aspen, Birch, or Willow, or any other kind of tree not desired in the crop, should be cut out.

When once these dangers are over, careful inspection of all young plantations should be made to see that fungus disease has not obtained a foothold from which it may spread, and that insects are not attacking the young plants.

Osier-holts should be weeded and cleaned by frequent holing and forking between the lines in spring and early summer, or only a light crop of rods will be harvested. For the first two years this costs about 30s. an acre, but after that much less; as the osiers, if kept clean in spring, grow quickly, and soon suppress weeds.

When the young woods or plantations grow up and form thickets, *thinnings* become necessary, usually between 15 and 20 years of age, according to the kind and quality of crop, the number of stems per acre, &c. And long before this time any *nurses* that were interplanted should have been cut out. The given local conditions as to crop, soil, situation, and the intentions of the proprietor determine, in fact, when and to what extent the first and all the subsequent thinnings have to be carried out; and to attempt to lay down general average figures as to the amount to be cut out, its net local value, and the number of stems that can best be left standing per acre, would only be misleading, as they vary so greatly for different localities and for each kind of tree crop, pure or mixed.

After the struggle for existence has commenced in earnest,

poles or young trees may be roughly classified as (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 stimulating the rate of growth of the crop.

As the object of thinning is to try and produce the best ultimate crop, the thinnings should from time to time (about once every five years, if practicable) eliminate one or more of the following :—

- (1) All dead, dying, and badly diseased or insect-infested poles.
- (2) Badly-grown poles (*e.g.*, of crooked or forked growth), and poles of inferior kinds of trees interfering with the growth of more valuable kinds.
- (3) Poles of the better kinds of trees interfering with the growth of more valuable poles, whether of their own species or of other valuable kinds.

Even the lightest thinning should remove all poles of class (1) ; but how far, *if at all*, those of classes (2) and (3) can *with advantage* be cut out, depends upon the existing condition of the plantation or wood as to density and demand for light and growing-space—*e.g.*, Larch, Scots Pine, and other light-demanding Conifers need somewhat freer and heavier thinning than Douglas Fir, Spruce, Silver Fir, and Red Cedar ; and Oak and Ash more than Beech or Sycamore. The best general rule is, thin *early, lightly, and often* ; but what this may mean in any given case depends greatly on the kind of crop and its condition. The time when thinning should be heaviest and repeated most often is when pole-woods are getting past their most active rate of growth in height, for their crown-expansion sideways becomes more necessary than before ; and, of course, this need for expansion of crown- and root-system is greatest in light-demanding trees.

Thinning out of standards in copse only takes place at each fall of the underwood, and is then part of the regular clearance

of a proportionate number of the stores and trees in the different age-classes corresponding with the rotation of the underwood.

If broad-leaved trees cannot be thinned out at once (*e.g.*, Beech interfering with Oak, Ash, &c.) they can be *ringed* or *girdled* by cutting through the sapwood into the heartwood and left to season on the stump till the next convenient time for removing them. But this cannot be risked with Conifers, on account of the danger from insects.

Poles and trees to be thinned can best be marked with the *scribe* (Fig. 19) while in full leaf. It is best to fell and extract the thinnings during winter; but it can be done in summer, if more convenient.

Fig. 19.

Under our old national system of arboriculture, young plantations, as well as middle-aged and maturing woods, were habitually overthinned, and the trees therefore grew up much rougher and more branching than is now desirable; but if a rational amount of thinning be not done, the crops get too thick, and the crowns of foliage too small for healthy growth. The percentage of the crop that may advantageously be removed at each thinning will vary greatly according to the kind of tree and the age of the crop, the quality of the soil, and the elevation, exposure, and slope of the land; and it may vary from about 5 to 10 per cent of the standing crop at different ages.

Thinnings generally begin when the price obtained for what is cut out more than pays the cost of cutting and extraction; and, of course, the larger this income or partial return from the capital sunk in the plantation is, the less the net cost of a young crop just after a thinning. This tends to induce somewhat heavy thinning; but, if the woods are to be managed on purely busi-

ness principles, it is in the end more profitable to thin moderately, and at regular intervals of about 5 years, according to the given conditions, than to make heavy thinnings before the crop is nearing its maturity—when heavy thinnings removing about 15 per cent of the crop amount to *partial clearances*, which generally give good increment on the stems, hasten maturity, and promote seed-production, though increasing the risk of windfall. In Conifer woods intended to be worked solely for providing pit-wood timber, heavy thinnings by cutting out the largest poles may, however, prove the most profitable treatment.

Both in the early and in all later thinnings or partial clearances with or without underplanting, the principle should be carefully observed, that thinnings in young woods should not be heavy enough to induce an unnecessary amount of branch-formation interfering with the growth in height and depreciating the quality and value of the bole as timber, and that thinnings in older woods should not break up the leaf-canopy so far as to risk any soil-deterioration through unnecessary exposure to sunlight. Where heavy thinnings and partial clearances are made among light-demanding tree-crops, soil-deterioration can only be prevented by underplanting (*e.g.*, Oak with Beech or Hornbeam; Larch and Pine with Spruce, Douglas Fir, or Red Cedar), though such measures are not usually practised in Britain, and may perhaps seldom prove directly profitable. But soil-deterioration means a loss in capital, for it diminishes the market value of the land for timber-growing.

Pruning is not needed in highwoods grown in close canopy, but may sometimes be useful on standards in copse; but even then it is seldom profitable, as it tends to produce a strong flush of shoots along the bole, and may cause the trees to die off in the top (*stagheadedness*). Hardwoods stand pruning best, and softwoods worst; but in any case the wound-surfaces need to be made smooth and to be well tarred to prevent fungi causing rot. When hardwood branches over 4 inches in diameter are pruned,

it is best to prune about 3 ft. from the stem ; otherwise pruning should be done close to the stem, and first of all the lower side of the branch should be cut or sawn into, to prevent tearing of the bark when the pruned branch is falling off. Pruning should be done as early in autumn or winter as may be convenient (October best). Pruning-tools consist of tree-saws, tree-chisels, and knives with special lever appliances (parrot's-beak, &c.).

The Renewal of Woodlands.—In Britain the opinion has often been expressed that there should be a change of tree when mature timber-crops 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 prove that there is no danger of any highwood crop, grown in close canopy, exhausting or failing to protect the soil against sun and wind, so long as the dead foliage is left to form *humus*. Properly managed evergreen Conifer crops leave the land richer in plant-food than when originally planted with trees ; and soil temporarily exhausted by badly managed broad-leaved crops may be recuperated by a catch-crop of evergreen Conifers, and again become suitable for 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 Strathspey pine-woods, crop has succeeded crop from time immemorial, yet they produce good, sound timber.

Methods of renewal vary according to the form of the crop. **Simple coppices** are cut back to the stool with a clean slanting stroke as close to the ground as possible, and reproduce themselves by throwing out stool-shoots or root-suckers. In **stored**

coppice, along with the underwood the standard trees grown for timber are also removed in a more or less fixed proportion, all the trees of the oldest class (say of four or five rotations of the coppice) being felled together with an equal number of the next age-class, and the other younger age-classes cut in larger number, the object being at each rotation to remove those that are not well grown, and only to leave those that seem likely to continue growing well. As *sowing* is generably unsuitable in our damp climate, owing to thick and rapid growth of weeds, the renewal of **highwoods** takes place in Britain by *planting*, when clear-felling is adopted, as is usually the case; and here the planting area is cleared and burned to destroy the rubbish, and then replanted. *Natural regeneration* from self-sown seed is here only usual in the case of Beech woods on the chalk hills of southern England, and of Scots Pine woods in the Strathspey district of Scotland; but it might be advantageously carried out to a much larger extent than at present in most of our woodlands formed with deep-rooting kinds of trees (but not in Spruce woods), as Ash, Sycamore, Larch, Oak, Silver and Douglas Firs, Cypressess and Red Cedar, and most kinds of forest-trees come up fairly thickly wherever the soil is in good condition and not overrun with a rank growth of weeds—*provided always that rabbits are kept down*.

1. **Simple and Stored Coppice**.—Coppicing or cutting back is the simplest way of reproduction; and the more clay there is in the soil, the greater the reproductive power usually is. By cutting close to the ground a better flush is got of stool-shoots from most kinds of broad-leaved trees, and of root-suckers from Chestnut, English Elm, Lime, Robinia, Aspen, White Alder, and non-indigenous Willows and Poplars; and the stools last much longer than when high stumps are left. Coppice should be cut with a heavy well-balanced bill for small poles, and an axe for larger poles, as a saw leaves a rough surface holding rain-water and inducing stool-rot. The cut should be clean,

slanting, and low down (Fig. 20). Where the stools are worn out or stand too thin, the best and cheapest way of improving the crop is to *layer* or *plush* when felling the coppice by leaving as many small shoots as are needed, from about 1 to 2 in. in diameter. These 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 turf and earth taken up. It succeeds best with strongly reproductive trees like Chestnut, Ash, Elm, and Lime. The shooting is stimulated by making longitudinal cuts here and there through the bark, or by giving the shoot a sharp twist. Plashing must be done immediately after the fall of the coppice, and *before*

the stools have flushed new shoots, else the sap naturally gets drawn to these as soon as their leaves are formed.

To supply the youngest class of stores in coppice with standards, poles grown from seed or from root-suckers are preferable to stool-shoots; and it is best to leave a larger number in autumn than are needed, because many bend over during the winter, and then in spring they can be thinned out, leaving only those wanted. To provide young seedling stores for the next rotation of the coppice, stout transplants can be interplanted among the stools as soon as the fall takes place. The usual rotation for mixed coppices is about 14 or 16 years, and that for stored coppice 20 to 25 years, but simple coppice of Alder is generally cut at 30 to 40 years old, when it much resembles a young highwood.

The best time for coppicing is usually the autumn, but Alders on marshy ground can best be cut and removed during hard winter frost, Osier-holts from January onwards, and Oak-bark

coppices can only be cut in May when the bark strips. Standards in copse-woods should be cut immediately after the underwood.

Conversion of Coppice 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, only the inferior ones being thinned out during any subsequent fall of the coppice. As the standards spread their crowns, the underwood will diminish; but this cannot be avoided. Stout transplants of Oak, Ash, &c., may also be introduced on suitable land, as seedlings are always best. Another good method is to interplant Larch about 20 ft. apart. They may need some little protection during the first two or three years, but they outgrow the reach of the coppice-shoots, find a favourable environment, and grow up into fine stems.

2. **Highwoods** may be renewed by—

(1) *Clear-felling*, 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 the windward, or by a few trees being left on the ground as seed-bearers (Scots Pine).

(2) *Successive 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) *Occasional Falls* 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.

(b) *Natural Regeneration in Groups*, consisting in the simultaneous clearance of small patches throughout a whole crop of woodland to form numerous small family groups of seedlings, which are gradually enlarged till the whole area is regenerated.

(c) *Simultaneous 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.

Occasional falls are most suitable for ornamental woods and broad shelter-belts; *regeneration in groups or patches* for

any woods of broad-leaved trees and for Silver Fir; and *uniform natural regeneration* by successive partial clearances before, during, and after the good seed-years, for Beech, Scots Pine, and probably also Douglas Fir, Cypresses, and Red Cedar. Where blank spaces remain by any of these three different methods, they can be filled by planting the kinds of trees best suited to the soil and situation.

(1) **Clear-felling** is usual in Britain, except in Beech, Oak, and some Scots Pine woods, the whole of the mature crop being clear-felled, and the area prepared for planting as soon as possible. But where the Pine-weevil is to be feared, Conifer stumps must be grubbed or replanting delayed for 3 to 4 years, till the dry stumps no longer attract the beetle.

(2) **In Successive Partial Clearances** the young crop is raised from seed shed by parent trees forming the mature crop, which both furnish the seed and protect the young seedlings against heat, drought, frost, weeds, &c., until the young plants can thrive without further protection, or may even require more light, dew, &c.

(a) **Occasional Falls** 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; because this method changes their general appearance least, gives the best protection against wind, and offers good opportunity for making picturesque mixtures of trees by planting. In extensive woods worked thus, considerable regularity may be attained by dividing the woods into five or ten blocks and going over one each year, to remove as many of the mature, badly grown, unhealthy or otherwise undesirable trees as seems necessary.

(b) **Natural Regeneration in Groups** consists in clearing small patches here and there all over the area to be regenerated, and then gradually extending these clearances as seedlings establish themselves. The conditions requisite for success are that the trees must be firm against wind and the seedlings shade-

enduring, *e.g.*, Beech, Sycamore, Ash, Douglas and Silver Firs, Cypresses, Red Cedar, and Spruce in sheltered places.

(c) **Simultaneous or Uniform Natural Regeneration** throughout a whole mature crop is the usual way 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, where it might easily be greatly extended with much advantage. On the Continent there are three different stages of partial clearance in the mature crop—(1) **A preparatory fall**, to hasten humification of dead foliage, if the woods are in close canopy ; (2) **a seeding fall**, to stimulate seed-production by giving the tree-crowns more light and warmth ; (3) **gradual clearance** of the parent trees, as the young crop requires more light, warmth, and air. But these different partial clearances of the mature crop are not made with fixed regularity, as they vary greatly according to the crop, the soil, and the situation.

Natural Regeneration of Oak in Britain was originally solely by means of enclosure, with prohibition of grazing ; and this simple method, easy through acorns being usually plentiful every 3 or 4 years, still gives good results in both Oak and Beech woods in the forest of Dean.

Natural Regeneration of Beech on the Chiltern Hills is generally carried out, with little or no soil-preparation, by gradual clearances extending over about 10 to 20 years, during which regeneration is usually left entirely to chance, as seed-years (which can be foretold in the previous autumn by the thick flower-buds) recur every 7 to 10 years, and the soil is generally favourable to the growth of seedlings. But the Continental methods of assisting nature by herding cattle and swine in the woods, or breaking up the surface-soil to a depth of 4 or 5 ins. with a heavy iron *Danish roller-harrow* (drawn by 2 horses, and easily riding over tree-stumps and big stones), or hoeing strips of about $1\frac{1}{2}$ to 2 ft. broad at distances of from

3½ to 5 ft. apart, would prove profitable in establishing a better and thicker crop of seedlings. The removal of the parent standard trees takes place gradually, as the young crop outgrows danger from frost and scorching, and begins to suffer from the heavy overshadowing.

Natural Regeneration of Ash, Maple, and Sycamore is easy, as they produce seed abundantly every year or two. On woodland soil already carrying a mature crop natural regeneration of Ash, Sycamore, etc., often springs up freely without any special soil-preparation; and all the attention that the seedlings need for the first few years is protection against rabbits. **The English Elm** reproduces itself freely on suitable soil by throwing up root-suckers, which also require protection against ground game, while the **Scots** or **Wych Elm** produces good seed freely.

Birch regenerates itself very freely, and where seed-producing trees are to windward, self-sown crops can easily be obtained by merely enclosing the land and keeping off cattle, sheep, and ground game.

Natural Regeneration of Scots Pine is usually easy unless there be a strong growth of weeds; but the parent trees have to be soon removed to give the seedlings light. Where heather covers the ground, the seedlings come up in larger numbers and more regularly than where bracken, grass, etc., cover the soil. In Scotland, regeneration-falls are usually made at intervals of 2 to 3 years, by leaving only about 20 to 30 seed-bearing trees standing per acre. Where there is a very strong growth of heather, regeneration can be greatly assisted by grazing sheep to keep down the weeds; but as soon as the seed is ready to fall with the dry east winds in spring, the tract must be protected against cattle, sheep, and deer.

PART II.

THE MANAGEMENT OF WOODLANDS

CHAP.

- I. THE MEASUREMENT OF LOGS, STANDING TREES, AND WHOLE CROPS OF TIMBER, AND OF THEIR INCREMENT OR RATE OF GROWTH.
- II. THE THEORETICAL PRINCIPLES OF WOODLAND MANAGEMENT.
- III. THE MAKING OF A WORKING-PLAN.
- IV. THE VALUATION OF TIMBER-CROPS AND OF WOODLANDS.

CHAPTER I.

THE MEASUREMENT OF LOGS, STANDING TREES, AND WHOLE CROPS OF TIMBER, AND OF THEIR INCREMENT OR RATE OF GROWTH.

I. Measurement of the Cubic Contents of Logs, Trees, and Timber-crops.

1. **Logs.** — The British method is *square-of-quarter-girth measurement*, the mean girth of the log being measured half-way between the two ends, then divided by 4, and squared, and multiplied by the length of the log in feet. And if the girth be taken in inches, the product of the quarter-girth squared multiplied by the length in feet has to be divided by 144 to obtain the result in cubic feet. In practice, tables of cubic contents are used for ready reckoning, varying by inches in mean girth, and by feet in length (see Tables in Appendix I., pp. 147 to 150). But the *true cubic contents* of any log is equal to *length* $\times$ *superficies of middle section* = *length* $\times$ $(\pi \text{ diameter}^2 \div 4)$ = *length* $\times$ $(\text{diameter}^2 \times 0.785)$, which gives a result just $21\frac{1}{2}$ per cent more than that obtained from the square-of-quarter-girth measurement, *length* $\times$ $(\text{mean girth} \div 4)^2$. This shortage of $21\frac{1}{2}$ per cent. was originally intended to cover wastage in sawing and conversion.

For example, say a log measures 20 ft. long and 8 ft. in mean girth. Its *true contents* are $20 \times (8^2 \div 4 \pi) = (1280 \div 12.566) = 101.8$ cubic ft.; while its *square-of-quarter-girth contents* are $20 \times (8 \div 4)^2 = 80$ cubic ft. — or, if

the girth be measured in inches, $20 \times (96 \div 4)^2 \div 144 = 80$ cubic ft.; and the proportion of shortage is $101.8 : 80 :: 100 : 78.5$, or $= 21\frac{1}{2}$ per cent of the true cubic contents.

Quarter-girth measurement is also customary in British India; but in Canada, Australia, and New Zealand the American B.M. system of *board-measurement* is used, where the cubic contents are estimated on the number of superficial feet they will yield as boards 12 in. broad and 1 in. thick.

In all estimates and transactions concerning lumber, felled or standing, the method adopted in the United States is *board measurement*, or B.M., the *board foot* unit being generally defined as a board 1 ft. long, 1 ft. wide, and 1 in. thick; but in actual trade practice it is 144 cubic in. (or $\frac{1}{12}$ of a cubic foot) of manufactured lumber in any form. In buying logs by this B.M. measure, one must first estimate what each log will yield in 1-in. boards. For this purpose timber-tables are used, which give in board-feet the contents of logs of various lengths and diameters. Under this system the buyer pays only for the saleable timber in each log when converted, while the inevitable wastage in slabs and sawdust is not included. This is merely a different way of arriving at the object aimed at in the customary British "square-of-quarter-girth" measurement, which estimates the contents of a log to be $21\frac{1}{2}$ per cent below its true cubic contents; for 1000 board feet of wood (which are equal to $83\frac{1}{2}$ cubic ft.) are produced from a log containing about 110 cubic ft. in actual contents, thus allowing for a wastage of nearly 24 per cent.

But besides the reduction thus everywhere made in Britain by square-of-quarter-girth measurement, a *bark-allowance* is also customary, varying according to local usage up to $\frac{1}{12}$ of the mean girth, or 1 inch per foot; and this is equal to a further reduction of 16 per cent on the contents of the log as shown by square-of-quarter-girth measurement, and to 20 per cent of the true cubic contents. But for thin-barked trees, like Spruce, Silver Fir, and Beech, this would often be an excessive allowance.

In the above example of a log 20 ft. long by 8 ft. mean girth, the full bark-allowance would be 8 in., and the cubic contents *below bark* would be $20 \times (88 \div 4)^2 \div 144 = 67.22$ cubic ft., or a further proportionate reduction on the customary measurement of $80 : 67.22 :: 100 : 84$, or $= 16$ per cent of the *square-of-quarter-girth contents*; and $78\frac{1}{2} : 100 = 16 : 20$, or 20 per cent of the true cubic contents. Thus the British landowner selling 100 cubic ft. of standing timber may only get paid for $100 - (21\frac{1}{2} + 20)$

=58½ cubic ft., and has also to throw in the "lop and top" to the buyer, to take or leave as he likes. This is not so on the Continent, and this should be borne in mind when comparing prices of timber per cubic foot.

When long trunks are being measured, if not already logged at parts where there is a stop or strong falling-off in girth on account of a big branch having been removed, each such section is measured as if it were a separate log. For girth measurement a string, tape-line, and steel-tape are all used, but the last is the best, as stretching less than tape-line, while string lends itself to cheating.

2. **Standing Trees.**—In Britain it is customary to estimate only the quantity of timber contained in standing trees, and *the definition of timber* varies locally; but everywhere it includes, besides the stem, all branches down to 6 in. in diameter free of bark, and sometimes even down to 3 in. in diameter (as for pitwood), while a division is often made into 1st class timber of 12 in. and above in quarter-girth, and 2nd class of under 12 in. quarter-girth. Small branchwood below timber-size is classed as *lop and top*, which the buyer can take or leave as he pleases, without payment; and this is supposed to be a set-off against the charge of felling and logging. In Britain standing trees are usually girthed about 4 to 5 ft. up (preferably at breast-height, 4½ ft.), then the height of the bole or the length of each section of 1st and 2nd class timber roughly measured with rods or estimated by eye, and the mean girth of the whole or of each section also estimated by eye. Another method is to measure the girth at breast-height, estimate the height of the tree up to where it has a diameter of 6 in. free of bark (=20 in. girth), and then estimate the cubic contents. But these ocular estimates, customary in measuring field and hedge-row trees, may be very inaccurate; and it would be far better if, in selling timber, it could be arranged for exact measurement in the log after felling.

The Continental Method of measuring Standing Trees is

to ascertain the *height*, the *girth* or *diameter at breast-height* ($4\frac{1}{2}$ ft.), and the *form-factor* or proportion which the true cubic contents of the tree bears to a cylinder of similar height and basal area [form-factor = actual contents of tree $\div$ (height $\times$ basal area)]. This method gives the true cubic contents and makes no allowance for wastage or bark; but it is only applicable to tree-crops growing in much closer canopy than is customary in Britain.

The height of the tree is measured with instruments called *Hypsometers*, of various kinds, which are all based upon the

Fig. 21.

The Measuring-Board.

geometrical fact that in similar right-angled triangles the respective sides are proportionate. The best and handiest of these instruments are the *Measuring-Board*, the *Mirror-Hypsometer*, and the *Telescope-Hypsometer*; this last being perhaps the most convenient and reliable.

The **Measuring-Board** (Fig. 21), about 8 inches square and an inch thick, is divided into squares numbered off in units, fives, or tens, and has a deep notch along the line of sight to the top of the tree. It may either be held in the hand or fixed sideways, by a screw in the centre, to an upright staff shod with iron, which can be inserted into the ground

while a reading is being made. The board being adjusted so that the top line Aa meets the top of the tree C (or the "timber-height" of the stem, if this is being measured), then, in the similar right-angled triangles ABC and abc , $BC : bc = AB : ab$. As AB has been measured and ab corresponds with this distance, the reading bc will at once give BC , to which, if the observation be made on level ground, must be added the height from the ground to the eye of the observer. On hillsides a double

Fig. 22.

reading may be added to or subtracted from the original observation, according to the observer's position.

For example, if AB , measured, is 70 ft.; then, when Aa has been adjusted in line with C , the reading bc (b being point 70 on the side scale) will correspond with BC , and can be read off as de on the scale along

The Mirror-Hypsometer.

the base of the board. If $de (=bc)$ is 45 ft., then BC is 45 ft., and the total height of the tree (BC and BD) will be 45 ft. plus the distance of the observer's eye above the ground.

Faustmann's **Mirror-Hypsometer** (Fig. 22) is on the same principle. The distance of the observer from the tree having been measured, the movable upright arm is set accordingly. When short (0-15 yards, or multiples of 0-15 ft.), the end of this marked II . is adjusted on the right-hand scale, to form the similar triangle; while for longer distances (15-30 yards, or multiples of 15-30 ft.), the end marked I . is set against the scale on the left-hand side representing the number of yards (or multiples of feet) between the observer and the stem. The observation is made through an aperture

in a small metal disc at one end, and by a hair-line stretched across a metal frame at the other end. In Fig. 22 it is set at 26 yards, and the reading on the mirror gives the result as 8 yards or 24 ft., to which, if the observer be on a level with the tree, must be added the 5 or 5½ ft. from the ground to the eye, or a supplementary observation has to be made from the horizontal to the foot of the tree, and added to or subtracted from the original reading.

Weise's **Telescope-Hypsometer** (Fig. 23) also rests on the same principle, but is made of brass, with a heavier weight to steady the free perpendicular, and a toothed base to help to bring the perpendicular

Fig. 23.

The Telescope-Hypsometer.

The end near the eye-hole takes off, so that the upright and the weighted rod (which is triangular, to catch more easily on the toothed scale) can be placed inside the tube when not in use.

ular fall into the toothed scale along the base. The perpendicular rod being finally brought to rest, the number it registers gives the height of the tree above the observer, to which the usual addition or subtraction must be made if the horizontal base-line be above or below the tree-base.

In place of measuring the girth as is usual in Britain, Continental foresters measure the diameter at breast-height by means of callipers graded so as to give either the girth or the diameter (or both). In using callipers it is best to measure the stems alternately N. and S., or E. and W., so as to eliminate errors arising from eccentricity in growth; but the most exact way is to measure two diameters at right angles to each other and take the mean of the two. The best form of calliper

soon to rest and simplify the reading of the height. The distance from the tree having been measured and the movable upright arm set accordingly, the observation to the top of the tree (or to the "timber-height") is made through the telescopic tube, which is turned gently round to the side from time to time to assist the loaded perpendicular to become steady and let the perpendicular

is that shown in Fig. 24. The movable leg *b* is enclosed in a case *D* in such a way that the fixed scale *A* has a narrow free space both before and behind, to reduce friction. The base *A* rests on a metal wedge *c*, which can be tightened or loosened as necessary by keying it up with the screw *d e*.

For scientific investigations extending over several years *automatic girth-measurement* at breast-height can be secured by placing thin ribbon-

Fig. 24.

Best form of Calliper.

like lead bands round the stem, and tacking them on with small staples, then marking where the outer one's edge overlaps the inner; and the readings can be made as often as desired (annually or monthly).

In measuring sample-plots with callipers, two or three men can do the measuring while the forester registers the girth or diameter each calls out, the register varying by 3 in. for girth, or inch by inch for diameter ($13\frac{1}{2}$ to $14\frac{1}{2}$ being graded on calliper as 14 in., and so on). A convenient form of register is—

Girth.	Diameter.	Larch.	Total.
At breast-height.			
inches	inches.		
42	14		17
45	15		23
48	16		19
and so on.			

3. **Whole crops of Timber** are best measured by selecting one or more sample plots representing a fair average of the whole crop, and carefully ascertaining their cubic contents, and then multiplying the result by the proportion which the whole crop bears to the sample plot or to the mean of the several sample plots measured.

The diameter (or girth) of all the trees in each sample plot having been measured and registered in a field-book showing the different kinds of trees and different diameters, varying by 1 in. (or girths varying by 3 in.), the diameter or girth of the true average sample stem can be found by the simple rule that *if four-tenths of the total number of stems in a measurement of the whole crop or of a sample plot of average quality be taken, and a count back made to this extent from the largest stem downwards, the result will invariably indicate the diameter - class containing the mean average stem for the crop or the sample plot.*

Diameter.	Girth.	Larch.
Inches.	Inches.	Total.
6	18	43
7	21	131
8	24	190
9	27	412
10	30	700
11	33	547*
12	36	356
13	39	181
14	42	99
15	45	45
		2704

For example, say a 3-acre plot of Larch contains 2,704 trees as here registered, then the true mean average stem will be found by taking four-tenths of 2704, *i.e.*, 1081, and counting back for this number from the largest diameter-class downwards, which leads one to the 11-in. class.* By selecting and carefully measuring the cubic contents of one or more average specimens of this class, taking their mean, and multiplying the result by 2704, the cubic contents of the whole 3-acre plot will be found.

Having ascertained the true average diameter-class, one then seeks out stems of this true mean diameter, measures 2 or more such mean stems accurately (felling them for this purpose, if

permissible), takes the mean cubic contents of these true average stems and multiplies this by the total number of stems in the crop or the sample plot to find total cubic contents. And of course in the case of a sample plot the result is multiplied in due proportion to give the cubic contents for the whole crop.

This measurement by sample plots presumes that each crop is sufficiently regular to permit of sample plots being taken so as to give a correct average for the whole crop or wood. In Britain it is usually extremely difficult to select true average sample plots, owing to woods having generally been over-thinned and often also damaged by wind; for a true result can only be obtained when the sample plots represent a true average of the crop. But wherever the crops are growing regularly and in fairly close cover, this is the best method of estimating the cubic contents of mature or maturing crops for the purpose of making a working-plan. In pole-crops 1-in. diameter-classes are most convenient, and for large tree-crops 2-in. diameter-classes,—the poles in each 1-in. class including all those, say, from $4\frac{1}{2}$ in. to $5\frac{1}{2}$ in., as 5 in., $5\frac{1}{2}$ in. to $6\frac{1}{2}$ in. as 6 in., and so on; and here also, to eliminate errors of eccentricity, the stems should be measured alternately N. and S. and E. and W., if callipers be used; while if an oiled linen or a steel tape be used for girthing, it should be pulled from side to side to get it as near truly horizontal as possible.

On the Continent the cubic contents of woods of different ages can also be estimated fairly accurately from **Average Yield Tables**, giving the average cubic contents of similar crops that have been carefully measured after felling. These tables are framed for different kinds of timber and different qualities of land; but except as indicating what can be grown on the Continent under good management, they are of little or no practical use for Britain, and therefore need not here be referred to in detail.

II. Estimating the Age of Logs, Trees, and Timber Crops.

1. **Logs.**—The age of logs can be estimated by counting the annual rings at the butt-end of the lowest log or on the stump, and allowing three or four years for growth up to that height. And similarly the diameter or girth at any particular age, as also the rate of growth from time to time, can be ascertained by counting the annual rings and measuring the results for comparison.

2. **The Age of Standing Trees** can be told with fair accuracy in the case of Conifers forming regular branch-whorls—such as Pines, on which the whorls can often be counted back for 30 to 40 years. Otherwise one can only estimate the apparent age from the height and the girth, and taking into account the quality of the soil, unless there are records as to date of planting or regenerating. By felling an average tree, however, the age can easily be determined by counting the annual rings at the stump.

3. **For Whole Crops of Wood** the mean age can also be easily ascertained in fairly even-aged woods by felling a stem here and there, counting the annual rings on each stump, and taking the average of these. But when patches of wood of different ages are comprised within a compartment, the average age for the whole compartment can be ascertained by taking the mean arithmetical average, stems being felled to fix the age of each patch, if necessary.

For example, suppose that, in a compartment of 12 acres, there are 5 acres of 50 years old, 4 acres 60 years old, and 3 acres 70 years old, then the true average age for the whole compartment would be $= [(5 \times 50) + (4 \times 60) + (3 \times 70)] \div 12 = 58\frac{1}{3}$ years.

III. Measurement of the Increment or Rate of Growth on Logs, Trees, and Timber Crops must be made in order to have the necessary data for making a working-plan.

The **Annual Increment** in any timber-crop consists in growth in height and growth in girth.

Growth in Height is most energetic during the pole-wood stage of development, but begins to fall off when trees require an increased individual growing-space enabling them to expand their crowns. Hence, although light-demanding trees are usually more rapid in early growth than shade-enduring trees, yet the latter generally continue longer in active growth in height. Conifers generally—and in particular Larch, Spruce, and Firs, less so Pines—have a more continuous tendency to upward growth than broad-leaved trees. But light-demanding trees require thinning earlier and oftener than shade-enduring kinds, and this necessity for lateral expansion of course exerts an unfavourable influence on the continuation of good growth in height. For any one kind of tree, however, the growth in height depends to a great extent on the quality and especially on the depth of the soil, and on the amount of thinning that has taken place; because thinning, by encouraging growth laterally, tends to limit the height-growth.

Growth in Girth is more or less proportional to the height and the breadth of the crown, the quantity of foliage, and the intensity of the sunlight; and it attains its maximum when the crown of foliage is largest in proportion to the girth of the stem. Thus there is always a very noticeable increase in the width of the annual rings formed just after a thinning has taken place, this increase being due to the larger production of foliage; and the total increment in wood for any given soil and situation depends mainly upon the amount of foliage and the intensity of the sunlight operating upon it.

As growth in height is—at first, at any rate—stimulated by keeping the woods close, and as growth in girth is stimulated by free thinning, the largest increment can only be obtained by trying to strike a suitable mean between not thinning sufficiently and overthinning. Hence, for every kind of tree-crop and for every stage of its development, there is, for any given quality of land, *a normal density of crop* tending to combine a good

growth in height with a fair growth in girth, so as to give the best obtainable increment or largest growth in cubic contents. It is therefore only reasonable to expect that neither crowded plantations, which produce long and slender poles, nor over-thinned woods, which produce stems thick at the base, but short and tapering, will give the largest annual increment obtainable from the given soil.

1. **The Measurement of Past Increment on Felled Trees** can easily be made by counting the annual rings on cross

Fig. 25.

Pressler's Borer.

sections, and thus ascertaining the increase from year to year, or in periods of five or ten years.

2. **The Measurement of Past Increment on Standing Trees** can easily be made at breast-height with *Pressler's borer* (Fig. 25), consisting of a hollow handle *a*, into which fits a hollow gimlet, *b*, for boring into the stem, and a long, flat pin *c*, toothed inwards towards its head and marked in inches and lines on the convex side; and both the pin and the gimlet can be packed in the hollow handle, one end-knob of which

unscrews for this purpose. The borer is placed against the stem at breast-height and firmly screwed in at right angles to the surface, and as far as desired. Then the toothed pin *c* is pressed home, the gimlet reversed for a few turns, and the spill *d* extracted.

A spill having been taken by means of this borer, the number of annual rings in the last inch of radius of wood formed can be counted, not including bark or outer cambium, and this gives the number of years taken for the stem to increase by the last 2 inches in diameter, or $6\frac{2}{3}$ in. in girth; and from this one gets a very good indication as to whether the tree is making fair increment or not. The most correct results are got with two borings at right angles to each other, and taking the mean of the two (as also in case of measuring the diameter of a tree). And as, except when a thinning takes place, the rate of growth for the next 5 or 10 years will probably be much the same as during the last 5 or 10, one can estimate the mean *percentage of increment* approximately by either of the formulæ $\frac{D^2 - d^2}{D^2 + d^2} \times \frac{200}{n}$ or $\frac{D - d}{D + d} \times \frac{400}{n}$, where *D* is the present diameter (below bark) and *d* the diameter *n* years previously (Pressler's formula, and Schneider's).

For example, in a stem of 20 in. diameter (free of bark) two spills taken at right angles at breast-height show 11 and 9 annual rings for last inch of radius, then the mean is 10 years for the girth-increase of $6\frac{2}{3}$ in. ; and the first formula will indicate a mean percentage of increment = $1520 \div 724 = 2.099$, while the second indicates = $80 \div 38 = 2.105$.

3. Estimate of the Increment in whole crops of timber can be made by the examination of sample plots or by means of Average Yield Tables, although the latter method is only applicable when the woods are fairly regular and in normal density. In general, the height of the crop and its appearance give a fair indication as to whether the wood is still growing well or not. But if one wishes to ascertain whether it is more

profitable to fell a mature crop now or n years hence, one can easily find this out by means of a simple formula giving p the percentage of increment obtaining throughout any given period of n years and expressed in terms of the capital (in timber or in money) at the middle of such period :—

$$p = \frac{\text{future yield} - \text{present yield}}{\text{future yield} + \text{present yield}} \times \frac{200}{n \text{ years}}$$

This is simply an expansion of the formula for the percentage of increment now accruing annually on the present cubic contents, from the simple proportion that the present cubic contents are to the present annual increment as 100 to the percentage of

increment (p); therefore $p = \frac{\text{annual increment}}{\text{cubic contents}} \times 100$ for any

one year; but if a period of 5 or 10 years or more is being dealt with, then the average for such period is

$$p = \frac{\text{mean annual increment}}{\text{cubic contents at middle of period}} \times 100. \text{ Thus, if } C_a \text{ be}$$

the present capital in wood (or in its equivalent, money or net income) and C_{a+b} what it will have grown to n years hence, then $(C_a + C_{a+b}) \div 2$ will be the mean capital or cubic contents over n years, and $(C_{a+b} - C_a) \div n$ the mean annual increment;

therefore $\frac{C_a + C_{a+b}}{2} : 100 :: \frac{C_{a+b} - C_a}{n} : p$; and p , the indicating

percentage of growth or increment over n years,

$$= \frac{C_{a+b} - C_a}{C_{a+b} + C_a} \times \frac{200}{n}$$

For example, suppose a timber-crop is worth £100 per acre to-day, and is likely to be worth £140 ten years hence, what is

its mean percentage of increment? Here $p = \frac{40}{240} \times \frac{200}{10} = 3\frac{1}{3}\%$.

If, therefore, the owner thinks timber-growing an unprofitable business unless he can get a return of $3\frac{1}{2}$ per cent on the

capital, he will cut this crop now; while, if he be content with 3 per cent, he will consider the rate of growth quite satisfactory. In the above example money or net income has been dealt with; but the reckoning is similar, and the result identical, if C be expressed in cubic contents per acre.

CHAPTER II.

THE THEORETICAL PRINCIPLES OF WOODLAND MANAGEMENT.

The Management of Woodlands treats of the best way of carrying out an owner's intention regarding his woodlands, so as to get continuously the largest annual income obtainable from the given capital represented by the land and the timber-crops suited to the soil, climate, elevation, exposure, &c. And in State forests and large private woodlands the management also deals with the organisation of the administrative and executive staff.

The **capital** required in forestry consists partly in land and partly in the growing timber-crops. In highwoods worked with a long rotation the capital in wood forms by far the greater part, whereas in copse-woods with a much lower rotation there is less difference in the proportion between the two forms of capital. But as regards woodlands it should be noted that the commodities they produce—timber, fuel, bark, &c.—are exactly of the same description as part, and generally the greater part, of the capital which produces it. Hence the annual falls must be carefully regulated so as neither to decrease seriously the capital in wood nor yet fail to harvest the greatest possible annual increment. One must therefore distinguish carefully between capital and increment, and must every few years take stock of the capital in wood, to see that only a proper quantity is being cut. The amount of the produce harvested can be

expressed either in cubic contents of timber or in their money value—the former being most convenient for the practical operations and the latter the better for fixing the best rotation for working, after comparing one method with another as to probable profit. The capital required is much smaller for coppices worked with, say, 12 to 15 years' rotation than for highwoods worked with 60 to 100 years' rotation. But as coppices, with or without standards, are now not nearly so profitable as they used to be, they are in many cases gradually being converted into highwoods, with or without interplanting.

Woodland Products may be classed as *major produce*, including timber and fuel, and *minor produce*, including bark, tree-seeds, resin, grazing, &c. The *major produce* includes both the *mature fall* or *final yield of timber*, and the *thinnings* or *intermediate returns* which may be obtained from time to time.

In forestry on a large scale one great object must be to make woods yield given kinds of timber in about equal quantities from year to year. If supplies are irregular in quantity or in quality, the consumer will prefer to get foreign wood from a merchant who can ensure him a steady supply. But the small woods so common in Britain must needs be worked intermittently; though, even then, measures may be taken to secure a proper amount of thinning, cutting at the best age, and efficient planting or natural regeneration. But these woods produce only a comparatively small amount of timber, and have very little effect upon the normal conditions of supply, demand, and price.

In extensive woodlands the case is different, for the main aim is to have regular supplies of timber and wood of various sizes in about equal quantities annually. To ensure this, the woodlands must consist of a regular series of crops varying in age from each other either by one year only (as in the clear-felling of annual falls of Pine, Larch, &c.), or else by such

a number of years as may be included in periodic falls (and usually of 20 annual falls) for natural regeneration (*e.g.*, Beech and Silver Fir). The series of falls need not succeed one another consecutively like one long arithmetical progression; but they must be all represented within the area under management (*working circle*), otherwise a regularly sustained annual fall is impossible. Some sort of **Working Plan** or definite **Scheme of Management** is therefore necessary in order to get woods into such a condition that they will yield the largest profit consistent with due security for future maintenance—unless the woods are intended for ornament or game coverts, as is often the case in Britain, or when business principles are not applied.

A **Working Plan** aims at bringing all the woods into a sort of ideal state or **normal condition**, which would consist in—(1) *a normal succession of crops* or regular series of woods of all ages from seedling up to mature tree, each age-class occupying an equal or equally productive area; (2) *a normal density* or full stock throughout the whole of each such area; (3) *a normal increment* or rate of growth of all the various crops, so that the annual increment throughout each age-class is fully proportionate to the quality of the soil and the situation; and (4) *a normal distribution of the annual falls*, the crops of various ages being so arranged that falls can take place regularly within suitable areas, although not necessarily in close succession year by year. Given these four conditions, the result would be (1) *a normal growing-stock or capital in wood*, with a regular series of annual or periodic falls distributed over the working-circle, and (2) *a normal increment* proportionate to the quality of the land, and producing equal returns in timber year by year.

As regards (1) *normal age-classes*, say 2000 acres of wood are worked with a rotation of 100 years; then (if all the land were of equal quality) there should be 20 acres each of crops from 1

to 100 years old, which could be more conveniently classed in 5 *periods* or age-classes respectively, I. 81-100, II. 61-80, III. 41-60, IV. 21-40, and V. 0-20 years old ; and the area of each such periodic age-class should be 400 acres.

(2) *Normal density* is a relative term depending on the kind of tree (according to its demand for light) and the climate, soil, aspect, &c. The better the soil and the situation, the quicker and the better is the growth, and the earlier and the more frequently is thinning needed ; but though the number of trees per acre be less, each is larger, and the total crop is bigger than on poor land. The normal density in central German forests varies as follows for the following kinds of trees on land of good quality for each given kind of tree-crop :—

Age of Crop. Years.	No. of Trees per acre.		
	Scots Pine.	Spruce.	Silver Fir.
40	720	1050	1370
60	370	500	520
80	240	310	310
100	170	240	220

(3) *Normal increment* also varies greatly according to kind of tree, soil, aspect, elevation, climate, &c., and differs at various ages, the most rapid period of growth being usually from 20 to 50 years of age.

(4) *A normal distribution of the annual falls*, such as would enable the timber to be most easily conveyed to the place of sale or consumption, and would really provide security against damage from wind, insects, fungi, &c., is hardly obtainable, and in practice one has to arrange the falls as seems best in the oldest and least satisfactory woods.

The normal growing-stock refers to the sum-total of the crops in all the age-classes. If a 100-year-old tree be cut, then the timber obtained comprises all the annual increments made by it each year up to 100; and if all the woods were in a normal condition the annual fall, including thinnings, would be equal to the total increment accruing each year throughout all the crops, so that the mature *annual fall*, plus the thinnings, would be equal to the *normal increment*.

A Normal Condition is, however, only a theoretical ideal to be aimed at; it cannot be attained, and it could not long be maintained. But the nearer one approximates to it, the more one gains its **ADVANTAGES**, viz.: (1) it enables regular annual supplies to be offered for sale, and thus helps to secure, utilise, and maintain any local demand for timber, &c.; (2) it affords more regular employment to labour, which may thus become cheaper and more efficient; (3) it ensures a regular annual income from the woodlands; and (4) it provides the best security against damage from wind, fire, insects, fungus diseases, &c.; while its only **DISADVANTAGES** are that (1) in trying to attain this ideal condition, some crops may have to be cut before they are fully mature, and others may have to be left standing though already mature, and (2) advantage cannot be taken of any temporary rise in price for any given kind or size of timber during any one season.

The Normal Capital in Wood may be roughly estimated as being equal to the *Mature Annual Fall* $\times$ the *No. of years in the Rotation* $\div$ 2. Here the *Mature Annual Fall* is the number of acres felled $\times$ the yield per acre in timber or its net market value. But this is only true theoretically and as a rough general approximation, because both the normal and the actual capital in wood or growing crops vary according to the rotation, kind of tree, soil, situation, climate, &c.; and this normal capital is annually diminished by the normal yield forming one year's fall, which is equal to the total growth for one year on

all the annual falls comprised within the working-circle. But this loss is annually made good by the normal increment, so that the normal capital remains theoretically the same from year to year, reckoned at midsummer. The normal capital in wood thus depends upon the length of the rotation and the normal increment proportionate to the kind of tree, soil, climate, aspect, elevation, &c.; and there must be a regular series of falls forming a simple arithmetical progression, although such a felling series need not necessarily be distributed in contiguous successive areas. Indeed, consecutive contiguous distribution is not desirable in practice, on account of danger from wind, insects, fungus diseases, fire, &c. And, of course, the area under each annual or periodic age-class must depend upon the kind of crop, soil, aspect, &c.

Rotation in forestry means merely the number of years elapsing between the formation of any woodland crop and its clearance or renewal when mature. Woodland soil does not deteriorate under proper management, but gradually acquires increased fertility or productivity, and especially in the case of Beech and other close-canopied trees whose dead foliage annually adds fresh humus to the soil. Sometimes a change may have to be made from hardwoods to Conifers owing to soil-deterioration, usually resulting from bad management; but under good management a change back to hardwoods may in course of time become possible, if then desired. The rotation varies according to the kind of tree, method of treatment, soil, aspect, elevation, climate, &c. Thus simple coppices may be worked with a rotation of 10 to 20 years, or stored coppice with 20 to 30 years, or Larch, Pine, Spruce, and other Conifers with, say, 50 or 60 years, Beech with 100 or 120, Oak with 140 or 150, &c., according to the given circumstances. And, of course, for any given total woodland area, the longer the rotation is, the smaller the annual fall will be; so that a private land-owner will naturally prefer to work his woods with a low

rather than with a high rotation. But besides reducing the area and the amount of the annual fall, a long rotation also adds considerably to the total amount of capital invested in and represented by the whole series of growing wood-crops; and the only advantage to be gained is that, with a high rotation, timber is obtainable of larger dimensions and worth more per cubic foot, and the thinnings in the maturing woods are also likely to be larger and more valuable.

The formula, *Normal Wood Capital* = *Annual Fall* $\times$ *No. of years in Rotation* $\div 2$, assumes that each unit of area in the series

Fig. 26.

of annual falls is stocked with a crop equal in amount to its age (number of years) multiplied by the average annual rate of growth of the mature fall of timber; but this is not in reality the case, as the rate of growth varies considerably according to the age of the crop, being most vigorous during the polewood stage of growth, although this variation does not affect the total volume of the mature crop when harvested at the most profitable age.

In Fig. 26, for example, it will be seen that, presuming the actual rate of growth of Pinewoods on medium land is as shown by the curved line, a rotation of 55 years would need only a somewhat smaller normal

wood-capital than the formula indicates, while a rotation of 65 years would need a somewhat larger amount than indicated. But by calculating as if the increment or rate of growth continued equal from year to year, it will easily be seen from Fig. 27 (a) that the formula gives a correct result—say, for a coppice worked with a 10 years' rotation, though it would apply equally to highwoods worked with a rotation of 50, 60, 100 or more

Fig. 27.

DIRECTION OF MOST DANGEROUS WINDS $\leftrightarrow$ (W WINDS)

COURSE OF THE ANNUAL FALLS $\leftarrow \uparrow \uparrow$ (E to W)

(b) Part of a Regular Course of Annual Falls distributed according to subordinate series of small partial falls recurring near same area only after intervals of 5 years.

(a) Regular Series of Annual Falls in close succession.

years. The series of growing crops over the whole woodland area for a 10 years' coppice rotation would be—

- (1) In Autumn, before the fall—1, 2, 3, 4, 5, 6, 7, 8, 9, 10 years old.
- (2) In Spring, after the fall— 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 years old.
- (3) At Midsummer, the mean of these— $\frac{1}{2}$, $1\frac{1}{2}$, $2\frac{1}{2}$, $3\frac{1}{2}$, $4\frac{1}{2}$, $5\frac{1}{2}$, $6\frac{1}{2}$, $7\frac{1}{2}$, $8\frac{1}{2}$, $9\frac{1}{2}$ years old.

The true mean at midsummer forms a simple arithmetical progression, whose sum is $= \frac{1}{2} (10 \times [\frac{1}{2} + 9\frac{1}{2}])$; and 10 is the number of years in the rota-

tion, while $\frac{1}{2} + 9\frac{1}{2} = 10$ is the mature yield or annual fall harvested every tenth year. Say, therefore, the area of the coppice working-circle were 80 acres, with a 10 year rotation, and the annual fall produced a net income of £5 per acre; then the total annual fall would be 8 acres, and its net value £40; and according to the formula the normal wood-capital invested to produce this result continuously would practically be $= \frac{1}{2}$ (£40 $\times$ 10 years), or £200 in all. And it is precisely the same with high-wood crops, even when they are subdivided into periodic age-classes and regenerated naturally—as, for example, in Beech-woods worked with 100 years' rotation and divided into five periods of I., 80-100; II., 60-80; III., 40-60; IV., 20-40; and V., 0-20 years, when each periodic class is regarded as having the mean average age of 90, 70, 50, 30, and 10 years respectively.

As regards choice of Sylvicultural Method, it is self-evident that **Simple Coppices**, worked with a low rotation, lock up the smallest amount of capital in wood, and permit a relatively large area to be felled annually; but they furnish only small-sized wood now of little value, such as hop-poles, pea- and bean-sticks, hurdle- and crate-wood, thatching-rods, faggots, &c.

Stored Coppice furnishes the same class of small produce from the underwood, but also gives a small proportion of larger poles, and of timber from the various age-classes of standard trees forming the overwood; and, owing to the standard trees, this method locks up more capital than simple coppice, although the proportionate area annually filled is just the same, being regulated by the rotation adopted for the coppice underwood.

Highwoods, worked with a longer rotation, give a relatively much smaller annual fall as regards area, though a much larger out-turn in timber; but they lock up far more capital in the growing-stock required.

Thus, for example:—

	<i>Annual Fall.</i>
(1) 600 acres with 15 years' rotation as <i>Coppice</i>	$= 40$ acres.
(2) " " " " as <i>Stored Coppice</i>	$= 40$ acres + standards of 30, 45, 60, and 75 years old.
(3) " 60 years' rotation as <i>Highwood</i>	$= 10$ acres.

For ordinary classes of highwood timber-crops on ordinary classes of woodland soil, profit is likely to be greater from quick-growing Conifers easily saleable at fifty or sixty years of age than from hardwoods such as Beech and Oak, which require ninety to one hundred and twenty years or more before reaching maturity or even fair marketable size. Hence, if any great scheme of national afforestation be undertaken, Conifers are certain to form the bulk of the crops planted. On the Continent Spruce with sixty years' rotation is found to be generally the most profitable kind of crop. But State Forests are often worked with longer rotations than private landowners care to adopt, in order to provide hardwoods of large dimensions, a supply of which may be very desirable from a national point of view, but which it would not be profitable for the private landowner to attempt to grow, especially under the existing estate and succession duty enactments.

Coppice used to be very profitable for small woodland areas, so long as there was a good demand for Oak-bark and small wood, the crops grown being chiefly Oak, Ash, Chestnut, Hazel, Maple, and Sycamore, with Alder, Willow, Poplar, Aspen, Birch, and Hornbeam on moister lands. And much attention was then given to see that stools were replaced whenever they began to lose their reproductive power. The best rotation to adopt for Coppice depends on the kind of crop grown. Oak-coppice is seldom now profitable; Hazel is often wanted only at about eight to ten years old, and Ash only at twelve to fourteen; and this makes it very difficult to now arrange for a good rotation for a mixed crop.

Stored Coppice or **Coppice with Standards** really needs a good fresh soil, otherwise the underwood does poorly under the shade of the standards, and the stools soon lose their reproductive power. Where such copses have become greatly deteriorated, the best plan often is to interplant with quick-growing Conifers, or transform the whole into a Conifer crop

when a fall is made, or else to "grove" the whole and allow it to grow up into a highwood (usually of poor quality) by simply thinning out the poorest and smallest poles. Returns from coppes are usually smaller than those from highwoods on similar soil and under similar circumstances; but the capital required is also less, and for woodlands of only about 200 to 300 acres it is often the most suitable method of treatment, because the English Settled Estates Act, 1882, makes an important distinction between coppice, simple or stored (*Sylvia cœdua*), and timber or highwood (*Saltus*), the life-tenant in possession of a settled estate being entitled to all the income derived from the former, but only one-fourth part of the latter, while the rest has to be paid over as capital to the trustees for the estate. Under Scots law, however, an heir in possession of an entailed estate can cut timber and put the money to his own uses without being impeachable for waste.

Stored coppice has the further advantages of being best suited for game coverts, and being on the whole the most ornamental kind of woodland, while it also allows of small quantities of valuable timber being grown for estate purposes, selected standards being left to mature as required.

Highwoods give the largest returns in valuable timber, and are best able to protect the soil from deterioration through sun, wind, and weeds, unless overthinned or otherwise damaged. As a rule, the fall should only take place after the average increment has culminated and the trees are of good marketable size; and where grazing is combined with wood-growing, that can in highwoods be carried on continuously with much less likelihood of damage than would be possible in simple or stored coppice.

It is difficult to draw any fair comparisons between these three different forms of crop so far as actual profits over a number of years are concerned. Where the soil is poor, the area large, and the capital of fair amount, then highwoods are

probably on the whole the most profitable, and especially when there is a good market for early thinnings. And highwoods are the only form of crop in which Pine, Larch, Firs, and other Conifers can be grown, which usually in Britain will prove the most profitable trees to grow.

The simplest form of highwood is where the whole area is regularly divided into annual falls, the oldest being cleared year by year, and a new crop formed by planting—as is usual with Larch, Pine, and Firs; but with Beech and Silver Fir it is common to comprise several annual falls within a periodic fall, and to clear the mature seed-bearing trees gradually from the area whilst a young crop is being naturally regenerated from the seed they shed. In some cases a few of the best trees are retained till greater size is reached, but this practice has several disadvantages.

Woods intended mainly for ornament, shelter, or game-preserving, are cut casually or sporadically, when the various age-classes are scattered irregularly over the whole area; but in such cases the mature trees are usually more branching and of less commercial value than when the woods are maintained in fairly close canopy.

As regards the Selection of Trees likely to form the most suitable and profitable crops in any given locality, consideration must be given (1) to the *Soil*, according to its nature, depth, and other physical properties, natural drainage, &c.; (2) to the *Situation* as regards aspect, elevation, configuration of its surroundings, shelter from gales, &c.; and (3) to *Facilities for Extraction and the Local Market* probably obtainable, both for thinnings and for mature timber. These and similar considerations will also mainly determine what seems likely to be the most profitable rotation; and when once the special kinds of crops and their rotations have been fixed on, this practically roughly indicates the general scheme of management that will have to be adopted; but *the most profitable rotation is that*

which exact calculations indicate as yielding the largest sustained net annual income from the total capital invested in land and crops, the calculations being made at compound interest, and being based upon the cost of formation, the time and net value of thinnings obtainable, and the final net income derivable from the mature crop (p. 143). In making calculations for future thinnings and mature falls, only *probable* returns can be dealt with; and even as regards income from past thinnings and fellings, cost of planting, &c., very few estates can furnish accurate statistics, while future changes in the market cannot be accurately forecast. The tendency of timber prices is upwards, and they are likely to continue to rise; but the market for small coppice material is gone, and seems never likely to revive.

Subdivision of Woodlands into Compartments.—At present British woodlands are usually scattered in small blocks over large estates, and are often not worked upon any definite principles at all; but to be able to introduce methodical management, all the woodlands on an estate should be subdivided into convenient *Compartments*, the *boundaries* of which may be roads, streams, hill-ridges, shooting-rides, inspection-paths, &c.; and they should be carefully chosen, because *the compartments form permanent subdivisions of the woodlands, and are the framework upon which any well-considered scheme of management must rest both now and in the future*. The *size and the shape of compartments* may vary according to local conditions; but rectangular boundaries are usually preferred, with the long side at right angles to the direction from which the prevailing most dangerous wind comes. The larger the compartment, the less is the acreage taken up by roads and rides, &c.; but compartments of about 25 to 30 acres are generally the most convenient, though where battue-shooting has to be kept well in view, smaller compartments of only 10 to 15 acres may be preferred. In making the compartments, *the network of roads* required for extracting the mature timber

and thinnings should first of all be laid out, though the roads need not be finished or metalled till required for heavy transport. *The boundaries* should be demarcated with numbered posts or stones, and *each compartment should be given a serial number*. Compartments in squares cause least waste of ground for roads and rides, while rectangular compartments enable the timber to be extracted with least haulage to rides or roads.

The advantages of having numbered and demarcated compartments are—(1) any part of the woods can easily and accurately be described or located on the map (*e.g.*, for timber sales, out-

Fig. 28.

breaks of fire, &c.); (2) they simplify the location, measurement, and revision of annual or periodic falls, as the boundaries are formed by roads, green lanes, or ridges; (3) they open up the woods and make extraction of thinnings and timber easier and cheaper; (4) trees next the boundaries become very firmly rooted, and thus minimise danger of windfall; (5) such breaks assist in putting out fires, when they occur; (6) they are useful for shooting purposes; and (7) they also help to reduce the danger from insects, fungus diseases, &c.

Each compartment should be formed of land of as uniform a quality as possible, so that it may consist of the same class of

wood. In hilly tracts the boundaries will usually follow ridges, valleys, and roads (Fig. 28); but on level land they may be set out in proportion of 2 to 1, or preferably 3 to 2, with the long side at right angles to the prevailing most dangerous wind (Fig. 29).

Fig. 29.

↙ N.W. Most dangerous wind, W.; next dangerous wind, N.W.
Periods I., II., III., &c. Compartments 1, 2, 3, &c.

WIND.

→ W.

5 III.	4 I.	3 IV.	2 II.	1 V.
6 II.	7 V.	8 III.	9 I.	10 IV.
15 I.	14 IV.	13 II.	12 V.	11 III.
16 V.	17 III.	18 I.	19 IV.	20 II.
25 IV.	24 II.	23 V.	22 III.	21 I.

← Felling Direction.

The Size of Compartments depends not only upon the total area of the woodlands, the manner in which the woods are scattered in blocks over an estate, the configuration of the land, the nature of the crops, and the specific form of treatment, but also upon the size of the working-circle (see below) to which they belong. They are larger in compact woods naturally regenerated than in small woods clear-felled and replanted, and larger on level tracts than on hillsides where

the quality of the soil is variable. They may be larger in broad-leaved than in Conifer woods, where danger from wind, insects, and fire is greatest. On the Continent the smallest compartments for highwoods are for Spruce. Boundaries may be 6 to 8 ft. wide in copses, and about 10 or 12 ft. in highwoods; but if intended for use as roads for extracting timber, they should be from 18 to 30 ft. wide. Main roads are broadest in Conifer woods, and should run in the same direction as the prevailing most dangerous wind (see Fig. 29).

When the whole woodland area has been broken up into a continuous series of convenient compartments, it should then be divided into **Working-Circles**, each comprising within itself the whole of the regular series of annual or periodic falls of the woods subject to same treatment, and forming a complete self-contained series of crops in more or less regular age-classes. Thus, while the compartments are the units of area in the woodlands, upon which any methodical scheme of management must be based, each working-circle (if there be more than one) includes as many compartments as form a complete series of crops of all age-classes up to maturity. It is not necessary to have a separate working-circle for each kind of wood grown, the custom being to form separate working-circles only for broad-leaved trees, for Conifers, and for woods under different kinds of treatment. Thus, on a large estate, one might have a working-circle for simple coppice, a second for stored coppice, a third for broad-leaved highwoods of Beech, Oak, Ash, Sycamore, Elm, &c., and a fourth for Conifers (Pine, Larch, Spruce, Silver Fir, Douglas Fir, &c.). Where ornamental woods in the vicinity of a house occur to any extent, they can be excluded to form a separate working-circle, and can be treated by means of occasional falls (p. 82, often called selection fellings).

Such principles are not as yet much acted on in this country, but they will have to be adopted if a national scheme of afforestation is begun, the first things necessary being to lay off a satis-

factory network of roads, and then to form compartments of convenient form and size according to the configuration, slope, and aspect of the land to be planted.

To be of normal condition each working-circle should have, for the given rotation with which it is worked, a regular series of age-classes on equal (*i.e.*, equally productive) areas, with a normal density of crop and a normal increment; while the annual (or periodic) falls should be so distributed as to lie in the proper direction of the fall against wind. It is neither necessary nor desirable that the annual or periodic falls should all lie contiguous; but the various groups formed of compartments belonging to the same working-circle should be as near each other as is practicable, though this ideal condition can seldom be attained in practice.

The Size of a Working-Circle may vary greatly. The higher the rotation, the larger must be the area to give continuously any fixed annual falls.

For example, say an owner wishes to cut 30 acres a-year, with a rotation of 50 years; such a Conifer working-circle would need an area of 1500 acres; but for a 60 years' rotation it would require 1800 acres.

The Allocation of Annual Falls, and the Formation of Felling Series.—The total woodland area, having been divided into compartments and the different kinds of crops grouped into working-circles, and the crop measurements and estimates having been made and tabulated (pp. 96-102, 126-132) and the rotation fixed for each working-circle (thereby also fixing the Annual Fall), one must then consider where the Annual Falls should be located. All timber-crops, and especially Conifers, are more or less exposed to damage from wind, frost, drought, fire, vermin, game, insects, and fungus diseases. Hence it is desirable to allocate the Annual Falls so as to give the best security against what seems the greatest of these dangers; and as in all except young crops this is usually Wind, it is gener-

ally desirable that the series of Annual Falls should succeed each other in the direction opposite to that of the most dangerous prevailing winds. Usually in Britain, and especially along the west coast, the S.W., W., and N.W. winds are by far the most dangerous; and the best protection can in these cases be given by making the Annual Falls succeed each other in the direction from N.E. to S.W., E. to W., and S.E. to N.W. respectively (see Fig. 30); but the trend of the winds often becomes much altered by the run of the valleys and the configuration of the country, and it often happens that very destructive gales come from a different direction to that of the prevailing strong winds. Making the Annual Falls run against wind also protects the soil. This measure is especially necessary with evergreen Conifers, and most of all for the heavily-foliaged, shallow-rooting Spruce; but it is also best for broad-leaved trees, as it favours natural regeneration, though not in the case of Conifers, whose cones open and shed their seed chiefly during dry E. winds in spring. But it is not necessary that the annual falls should form a contiguous series; in fact, keeping each two successive falls apart is desirable, especially in Conifer crops, on account of insects, fire, &c., the chief point to be kept in view being that the various annual falls, taken as a series, should be made in the direction against the most dangerous wind. And where large annual falls have to be made, it is best in Conifer woods to make several small falls in different parts of the woods, instead of one large fall, and to arrange that any two successive falls within the same compartment should take place, if practicable, only at intervals of 4 or 5 years, in order to prevent damage by Pine weevils. Supposing the compartments are each 40 acres, and the annual fall 20 acres, then it would be better, with a rotation of 80 years, to have 4 age-classes in each compartment, and to spread the annual fall over 2 compartments, than to have only 2 age-classes and cut one-half of a compartment at each annual fall.

It should also be noted that as the W. wind is supposed in this case to be the most dangerous, and then the N.W., each compartment in which falls are being made will have, for the young crops planted there, the protection of maturing woods for the next 40 years on the W. side, and of older woods for the next 20 years on the N.W. side.

In Fig. 30, a Scots Pine Conifer working-circle on a level sandy tract is shown, divided into 25 compartments, and worked with a rotation of 100 years divided into V. 20-year periods, the 20 Annual Falls throughout period I. being so distributed that there an interval of 5 years occurs between any two consecutive falls in any compartment, thus giving the greatest possible protection against wind, insects, and other dangers.

Fig. 30.

Most dangerous wind, W. ; next dangerous wind, N.W.
Periods I., II., III., &c. Compartments or annual falls, 1, 2, 3, &c.
A, B, C, D are the drives, or broad green lanes, or else roadways.
a, b, c, d are the narrow rides.

WIND.

	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>
A	III. 19 14 9 4	IV.	II. 17 12 7 2	V.
B	II. 20 15 10 5	IV.	II.	IV.
C	V.	III. 18 13 8 3	IV.	II.
D	IV.	II.	V.	III. 16 11 6 1
	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>

W. Felling Direction.

Severances are protective falls made when it can be seen long beforehand that a felling-series may have to begin at some place where the first clearance will leave the growing crop on the leeward side unduly exposed to danger from wind. To strengthen this windward edge that will then be exposed, a *severance* is made by clearing a strip of about 22 yards broad (1 chain) along the edge of the crop that will come to the fall, and replanting this strip, so that when clearance and exposure

take place 20 to 30 or more years hence, the then exposed windward edge of the compartment to be protected will be better able to resist the wind, and will also have the additional protection of the younger strip planted along the severance.

For example, a crop of 40 years old (Fig. 31) lies in the lee of a crop 60 years old, which will probably have to be felled about 20 years hence, before the former is mature. For the protection of the 40-year-old crop, when the annual fall cuts into the mature crop (then 80 years old) 20 years hence, the former should *immediately* be strengthened by a severance (*a b*) being made to a breadth of about a chain in the latter; and this cleared strip should be at once planted up.

Fig. 31.

Severances should be made early enough to allow of the trees along the windward edge of the compartment needing protection to strengthen themselves against wind by extending their root-system outwards. If the trees are already so old that they cannot do this to any extent, then making the severance is of little or no use. Hence the success of this measure depends upon the kind and age of the crop, the soil and situation, &c. But it is far more necessary for Conifer crops (and especially Spruce) than for broad-leaved woods.

Different methods of Fixing the Annual Fall.—Where only simple coppice or coppice with standards is concerned, worked with a rotation of, say, 15 or 20 years, then the equal, *i.e.*, equally productive, areas forming the 15 or 20 annual falls naturally range themselves into a simple felling-series from 1 to 15 or 20. And the same applies to the periodic block method of regenerating beechwoods on the chalk-hills of Southern

England, though practically here a number of annual falls is grouped together to form a periodic fall according to the interval occurring between any two successive good mast years. But with regard to Conifers and other highwoods formed without any definite scheme of management having been kept in view, as has often been customary in Britain, one must fix the rotation, estimate the growing-stock required, and then determine the area to be felled annually in order to maintain a continuous and regular income from the woods. The annual fall can be determined by one or other of the methods based upon (1) *the woodland area alone*; (2) *the yield or cubic contents of the crops*; and (3) *by a combination of the area and the yield*. For easy supervision in each of these three methods, the annual falls can be conveniently grouped into *periods or periodic falls*, each comprising the annual falls of 20 years; and more particular attention is devoted to falls in the first half of the oldest or I. period than to those in the second half, or in the II. or subsequent periods. With a rotation of 100 years there will be 5 periods, I. including the oldest woods, 81 to 100 years, II. those of 61 to 80, III. 41 to 60, IV. 21 to 40, and V. those up to 20 years old. And the I. period would be divided into the two sub-periods, I¹. and I²., respectively denoting woods of 91 to 100 years and 81 to 90 years; while the remaining periods need not be so subdivided.

(1) **Fixing the Annual Fall from the Woodland area alone** is the oldest and simplest method, the whole area being divided equally into the number of annual falls needed for the rotation, and the area in each case being therefore equal to the total woodland area divided by the number of years in the rotation. The great drawback to this very simple method is that it does not allow for differences in soil-productivity or as to the distribution of the growing-stock in the properly proportionate age-classes; hence, in order to ultimately equalise the areas felled in each period it might be necessary to cut some crops

before and some after maturity, with the result that a normal series of age-classes would be produced in the course of one rotation during which the annual falls might vary greatly in extent. Differences in soil-productivity can be counterbalanced by making the annual falls inversely proportionate to the quality of the land, as a smaller area of fall on productive land will give as large a yield as a proportionately larger area of less productive land. Hence, to get a sustained annual yield of about equal quantity and value, one must make larger falls on poorer land, and smaller falls on better land, so as to equalise the income year by year. This improved method of fixing the annual fall by equally productive area only is the most practical for simple and for stored coppice ; but it is unsuitable for highwoods, unless worked with a low rotation, *e.g.*, for pit-wood. For all ordinary highwoods the periodic arrangement is preferable.

(2) **Fixing the Annual Fall from the Yield or Cubic Contents of the Crops.**—Under this method, after the rotation has been fixed and the whole working-circle divided into 20-year periodic blocks, a tabular *working-plan* is drawn up in such a way as to give about an equal yield for each period, and the annual fall for each whole periodic section equals the total periodic yield divided by 20 years. This tends to equalise the fall, but does not necessarily lead to a normal distribution of age-classes, a normal growing-stock, and a normal increment. It is therefore not a good method. Although it may look all right on paper, it has no real practical value, because it is quite impossible to forecast exactly what the annual fall will be.

(3) **Fixing the Annual Fall by a combination of Area and Yield** is by far the best and most practical method. It was introduced on the Continent about 100 years ago, and is now everywhere in force there, though the precise method of its application differs in details, not only in different countries, but also in different districts throughout each country.

As the woodland area is the only factor that remains fixed and unalterable, this serves as the main basis for any good scheme of management. But as the condition and the distribution of the various timber-crops (as to age-classes, density, rate of growth, &c.) may vary considerably from a normal condition, the subdivision of the woodlands into approximately equal annual or periodic falls cannot of itself secure a more or less equal annual yield; and so the condition of the growing timber-crops must also be considered, and especially the condition of those coming to the fall within the next 20 years (I. Period).

The total woodland area having been divided into compartments and working-circles, and the method of treatment of the latter having been determined, the area needed for each working-circle is divided into as many periodic sections (usually of 20 years each) as are contained in the rotation; and such proportionate area of the working-circle is allotted to each of these periods as seems to consist of the most suitable crops, and to lead towards attaining a normal succession of annual falls in the direction against wind. This periodic division by area enables one to estimate, as nearly as is practicable, the yield of the falls during the first two periods, and to equalise the fall annually throughout each of these two periods, while considering the actual conditions of the crops coming to the fall within each.

As the proportion of different age-classes is important, a *register of crops* has to be drawn up showing the distribution of the different age-classes in each working-circle. These details having been registered in a tabular form which shows also the full crop-description, area, quality of land, age of crop, and present cubic contents and annual increment per acre, a **felling-plan** is made, allotting the various areas to the age-classes or periods to which they properly belong; but special consideration is given to the maturing crops in the first period, and for this purpose the first period, I., of 20 years is divided into two

decennial sub-periods, I^1 . and I^2 ., and particular attention is given to the distribution of the falls during *sub-period* I^1 ., towards the end of which a revision should take place for fixing the falls of the next 10 years; and so on continuously thereafter. The average fall for the I. period having been fixed, and the period subdivided into the two decennial sub-periods, a detailed examination of the cubic contents and the present rate of growth of the crops in each of these sub-periods is made, and the yield is then calculated (*including the accruing increment*) to the middle of each sub-period, and entered into the Felling-plan. The total fall for each of these decennial sub-periods being then divided by 10, gives the average annual fall in cubic feet per annum for each of the first 10 years, and also from the 11th to the 20th year. On the Continent, the exact locality in which each separate year's fall is to be made is not prescribed, it being left to the discretion of the head forester to fell where he may consider most expedient.

The falls for the II. period, 20 to 40 years hence, are also entered in the plan as regards acreage and yield, the yield being only roughly estimated, while for the subsequent periods only the area is entered, as it is still too early to estimate what the future yield will be of woods only maturing 60 to 100 years hence; nor would there be any practical use in doing so. Under this method, Beech and other broad-leaved woods in general are worked usually with a rotation of 120 years, divided into 6 periods, and Conifers with a rotation of 100 years divided into 5 periods; and every 10 years a revision takes place to fix the details for the fellings during the next 10 years. So far as fixing the falls for the subsequent 4 or 5 periods is concerned, the method is purely by area, but giving due consideration to soil-productivity.

The form in which such a felling-plan could be drawn up for Conifer highwoods worked with an 80-years rotation might be somewhat as follows:—

I. Period (1911-1930).						II. Period (1931-50).			III. Period.	IV. Period.	Remarks as to Treatment.
I ¹ . Sub-period (1911-20)			I ² . Sub-period (1921-30).								
Fall.	Yield.		Fall.	Yield.		Fall.	Yield.				
	Per ac.	Total.		Per ac.	Total.		Per ac.	Total.			
c.	c. ft.	c. ft.	ac.	c. ft.	c. ft.	ac.	c. ft.	c. ft.	ac.	ac.	
6	8,625	138,000									
			12	8,000	96,000						
						15	7,750	116,250			

increment for this period also as nearly as possible. As the end of sub-period I¹. approaches, a revision is made of the estimates of yield in the various remaining compartments, so as to be then able to determine more accurately what should be felled in sub-period I². And of course adjustments have often to be made between Periods I. and II., and between sub-periods I¹. and I². of Period I., in order to try and equalise the Annual Falls.

CHAPTER III.

THE MAKING OF A WORKING-PLAN.

LARGE woodland estates cannot be worked economically unless under some definite **Working-plan** or **Scheme of Management** showing the present condition of the woodlands and forecasting as simply as possible the annual operations during the next ten or twenty years (felling, thinning, planting, &c.). The data required for such a working-plan are, in the first place, *accurate estimates of area, growing-stock, and increment or rate of growth*; for it is only when these are known that the best method of treatment and the most suitable rotation can be fixed. The *6-inch Ordnance Survey Maps* are well suited to form the basis for a working-plan; but if there be no proper network of roads and paths, and no sub-division into compartments, all of these ought to be arranged for, in order to form the permanent framework upon which the scheme of management must rest. The most convenient size for compartments must vary according to circumstances, but is usually about 20 to 30 acres in large woodlands. A **register** has to be made out of all the crops, arranged according to method of treatment, and giving age and area (Age-Classes), and allotting them to working-circles according to the method of treatment required, each working-circle comprising one complete series of age-classes of all the woods or crops subject to similar treatment—*e.g., Ornamental Woods, Coppices, Highwoods*; and, of course, for highwoods worked by

different methods and rotations, there may have to be separate working-circles (broad-leaved and coniferous woods). It is also useful to note in the column for remarks how a felling-series should run (E. to W., &c.) so as to give the best protection against wind, &c. The **Quality of land** should also be noted for each crop, and the most useful way is to class it as I., II., or III., *good, medium, or poor*, noting also its *slope* (gentle, moderate, steep), its *aspect* or *exposure*, its *elevation*, and its *configuration*. A **Field-book** has to be opened in which to note these details, and also record the more particular description of each crop forming part of the growing-stock—the kind of wood, method of treatment, age, density and canopy, general condition, cubic contents and rate of growth, being all duly noted. The nearer the woods are to their maturity the more important does it become to know their cubic contents and their increment; because it is preferable to make a fall in a mature wood now growing slowly, than to cut down one that is still in good growth. Where a really scientific working-plan is desired, the estimate of the cubic contents and the current increment of all maturing crops (as indicated on page 128) is of particular importance, and more so than similar estimates regarding younger and immature crops. Notes should also be made concerning the best time of felling, and best method of regenerating the mature crop and of tending the younger crops. Where available, statistics should also be jotted down referring to past yield, income from and price of timber, cost of planting, &c. When this field-book has been completed for all the crops, the working-plan or scheme of management can be prepared.

Having ascertained that the whole woodland area is conveniently subdivided into compartments, and having made the necessary investigations into the various crops forming the growing-stock, and into their rate of growth, the next thing to be done is to ascertain the distribution of the relative **Age-**

Classes in the various working-circles, and to prepare a sketch **Felling-plan** according to area (see pp. 129, 135), then to fix the extent and allocate the position of the **Annual Falls**, and finally, to elaborate the **Working-plan** and prepare the **Explanatory Note** and the **Stock Map** which should accompany it.

To find the distribution of the different age-classes the crops in each working-circle are registered according to age in 20-year periods, when it can easily be seen how far each age-class varies from the normal proportionate area it should have; and it will be found useful to prepare at this same time a **Stock Map** showing the woodland area, its division into compartments, and the different kinds of crops and their respective periodic age-classes in each working-circle, giving to the youngest period (under 20 years) a light wash of any chosen colour, to the 21- to 40-year-old class a darker wash of the same colour, and so on for the older periodic age-classes. And if there are different working-circles (*e.g.*, for broad-leaved trees and for Conifers), different colours must be used for each working-circle. Woods under natural regeneration (*e.g.*, Beech, Silver Fir, Scots Pine) can be indicated by being given the palest wash and then having lines of darkest wash drawn across the ground colouring, thus indicating a combination of the youngest and the oldest age-classes until the mature seed-bearing trees are removed.

The **Felling-plan** according to area is first of all roughly sketched by allotting areas to the various periods according to their age, as shown in the register, so as to see how a convenient felling-series can be made, and also, with the assistance of the Stock Map, to note where severances may require to be made now, if necessary at all, in order to protect woods that may have to be exposed to winds later on. An important matter is to try and arrange the felling-series (of which there may be one or more, according to circumstances) in the direction likely to afford the greatest protection from wind; and it is also desirable to make intermittent felling-series in place of any

continuous series occurring on adjacent areas year after year, because it is only thus that attacks of pine weevils in Conifer woods can be prevented. In broad-leaved woods, however, there is no necessity for this, and the main object here is to try and arrange the falls against the most dangerous wind. In drawing up the rough sketch for the felling-plan, *areas are transferred from period to period*, and particularly during the I. and II. Periods, comprising the mature and the maturing woods, so as to get about an equal fall of mature timber from year to year, and gradually in course of time to attain a normally proportionate distribution of the various age-classes throughout each working-circle. A fair idea of the way of doing the above may perhaps be got from the example on pp. 134, 135.

In elaborating the felling-plan so as to estimate scientifically the annual fall to be made during the first 10 years and the second 10 of the first period (I^1 . and I^2 .), the total yield and increment must be worked out, the increment being calculated up to the middle of each sub-period—*i.e.*, for the next 5 years in I^1 ., and for 15 years in I^2 ., in the manner indicated on pages 128, 129.

But this necessarily means much more time and expense in preparing the Working-plan, so that the tabular statement on pp. 134, 135 will usually suit the conditions at present prevailing in British woodlands. Or something even simpler may perhaps sometimes be considered quite sufficient, on some such lines as the Working-Plan on pp. 136, 137.

The **Explanatory Note** gives first of all a brief description of the woodlands, and their soil, situation, condition, rate of growth, &c., then describes the object aimed at in the Working-plan, and states the reasons for the recommendations made as to kinds of crops, methods of treatment, rotation, and fixing the felling-series and the annual falls, and concludes by making any recommendations that may seem desirable regarding felling,

CROP-STATISTICS AND PRESENT DISTRIBUTION OF AGE-CLASSES.

Working-Circle for Conifers, on the

Woodland Area.				Growing-stock in 1900 : Age-Classes, in Acres.						
Compartment.		Area. Acres.	Qual- ity of land.	Age. Years.	I. (over 60 years).	II. (41-60)	III. (21-40)	IV. (1-20)	Falls for re- plant- ing.	Blanks and land for new planta- tions.
1. Briar Hill =37 acres.	a	16	II.	85	16					
	b	12	III.	74	12					
	c	9	II.	62	9					
2. Greenwood =36 acres.	a	21	II.	59		21				
	b	15	I.	55		15				
3. Round Hill =47 acres.	a	18	III.	33			18			
	b	16	III.	30			16			
	c	5	II.	20				5		
	d	8	II.	17				8		
4. Gorse Cover =24 acres.		24	I.	78	24					
5. Oakwood =33 acres.	a	10	III.	54		10				
	b	16	III.	45		16				
	c	7	III.	31			7			
6. Rushton Brake =31 acres.	a	13	II.	19				13		
	b	18	II.	18				18		
7. Frampton Hill =32 acres.	a	27	II.	12				27		
	b	5	II.	just felled.					5	
Total . .		240	II.		61	63	41	71	5	
Actual distribution of periodic age-classes					61	62	41	76		
Normal do.					60	60	60	60		
Variation from the normal dis- tribution }				excess	+1	+2	...	+16		
				deficit	...	...	-19	...		

PRELIMINARY SKETCH FOR THE FELLING-PLAN, ACCORDING TO AREA.

Frampton Estate (Rotation, 80 years).

Felling-Plan: Fall, in Acres.

I. Period (1901-1920).		II. Period (1921-1940)	III. Period (1941-1960)	IV. Period (1961-1980)	Remarks as to Treatment.
1. Sub-period (1901-1910)	2. Sub-period (1911-1920).				
<u>16</u>	12 9				1st Felling - Series ; compart- ments 1a, b, c ; 2a, b ; 3a, b, c, d. The falls in this series should precede those in the 2nd series. The annual falls being only 1½ acres, there will be little danger from weevils if re- planted after one year's fallow, and burning before planting.
Thin do.	Thin do.	21 15			
Thin do. do. do.	Thin do. do. do.	Thin do. do. do.	18 16 Thin do.	5 8	
<u>15</u>	9				2nd Felling - Series ; compart- ments 4 ; 5a, b, c ; 6a, b ; 7a, b. ¹ The sporadic softwoods should be cut out where interfering with the Conifers. ² Areas to be planted during the next 10 years are underlined (<u>16</u> , <u>15</u> , <u>5</u> , <u>31</u>).
Thin do. do.	Thin do. do.	10 11 Thin	5 7		
Thin do. ¹	Thin do.	Thin do.	13 Thin	18	
Thin (<u>5</u>)	Thin do.	Thin do.	Thin do.	27 5	
<u>31²</u>	30	57	59	63	

The distribution of the age-classes may also be shown graphically, thus:—

The Working-Plan.—Felling and Replanting may best take place as follows :—

I. Conifers: *Clear-Felling and Replanting with mixed Conifers* (Pine, with Larch and Douglas Fir).

Year.	Name of wood.	Number of compartments.	Present crop.	Area, exclusive of roads, &c.	Total fall for year.	Remarks as to treatment.
1900-01	North Wood	1	80-90-year mixed Conifers and hardwoods, chiefly Pine and Oak.	27	54	{ Fell from E. to W. to minimise danger of wind-fall. Burn area to clear it of rubbish and reduce danger from weevils, then plant with mixed Conifers, Fir, in groups (with Spruce in damp patches).
	do.	2	80-90-year mixed Conifers, mostly Scots Pine.	27		
1901-02	Dennie Hill	12	{ Mostly old Beech (140-160 years) and other hardwoods in lower part, with Pine (100-120 years) and mixed Conifers (about 60-70 years).	24	59	{ Do. do. Should be planted with pure Scots Pine on the poorest and most exposed parts.
	do.	13		35		
1902-03	Pond Wood	3	{ Chiefly Scots Pine (80-90 years), mixed with Spruce and a few Larch.	15	32	{ Fell from E. to W. Burn and replant as above. E. part requires drainage and planting mostly with Sycamore, Ash, Birch, and Spruce.
	do.	6		17		
1903-04	High Hill	16	{ Mixture of old Beech and other 90-year-old hardwoods and Conifers, mostly in patches.	40	40	{ Do. do. Opening out of old drains would be advantageous before replanting.
	do.	do.				
1904-05	Pond Wood	4	{ Much the same as compartments 3 and 6.	28	48	{ Do. do. Old curling-pond should be drained and planted with Sycamore and Ash.
	do.	5				
1905-06	Binn Hill	14	{ Partly hardwoods, partly Conifers, mixed in patches, mostly about 90 years of age, with some old Beech and Scots Pine.	23	23	As in 1.
	do.	do.				
1906-07	Dennie Hill	7	{ 60 to 70-year-old Scots Pine with a sprinkling of Larch.	32	59	{ As in 1; but E. portion requires drainage, and should be planted chiefly with Sycamore, Ash and Spruce; and exposed parts of 8 with Scots Pine.
	do.	8				

1907-08	High Hill West Cliff (upper part only).	17 18	{ Much the same as in compartment 16, but situation drier. 90-year-old mixed woods, chiefly Conifers.	{ 42 } { 11 }	53	{ Do. Parts of 17 may require drainage.	do.
1908-09	Dennie Hill do.	9 11	{ Mostly 80 to 90-year-old Pine and Larch, with pure Pine (100-120 years) along exposed S. face, and Spruce and Pine (50 years) in moist patches.	{ 25 } { 32 }	57	{ Do. 50-year-old Spruce and Pine cannot be protected from wind, and should be cleared with rest of crop. Plant Pine pure on the exposed knoll and the S. side of hill. Small young plantations should be filled up to 4 x 4 ft. with Scots Pine on dry parts, and Sycamore and Ash on moist patches.	do.
1909-10	Dennie Hill West Cliff (upper portion of each)	10 19 } 20 }	{ Partly mixed hardwoods (mostly old Oak, a very thin crop) and partly mixed Conifers (90 years). Mixed woods, mainly Conifers in patches.	{ 31 } { 5 } { 8 }	44	Do.	do.
					Total, 469		

II. Hardwoods : to be naturally regenerated and interspersed with Conifers.

1900-01 to 1909-10	Binn Hill West Cliff (lower portion of each)	15 18 } 19 } 20 }		23 { 22 } { 14 } { 12 }	Total fall during whole period of ten years. Acres. 71 Total, 71	{ Careful thinning of existing crop, and natural regeneration of hardwoods, with subsequent filling up with Larch, Douglas Fir, and Pine. Sycamore and Ash should be favoured in the natural regeneration, being likely to form the most profitable crop. Soil should be hoed in parallel strips, or raked with heavy rakes, horizontally along the hill sides, and sown with Sycamore and Ash wherever seed trees do not stand near at hand. The present trees to be then gradually removed according to the necessity of the young seedling crop, and Larch and Douglas Fir planted to fill blanks.	
					Add area of Conifer crops, Grand total,	469 540	

planting, tending, &c., including the keeping of a control book to show the results of the working year by year, and thus facilitate the revision which is necessary every ten years or so, and which is much easier than drawing up a Working-plan for the first time on any woodland estate.

Book-keeping is necessary for the proper management of woodlands, but it is desirable to limit the number to as few books as possible. Several are needed, however, in addition to the *Control Book* showing the results of working under any scheme of management—viz., (1) *Cash Book*, (2) *Monthly Abstract of Daily Labour and Piece Work*, (3) *Sales Book of Timber, &c.*, (4) *Ledger*, (5) *Stock-Book of Timber*, and (6) *A Nursery Stock Book*; and if there is a saw-mill, regular mill accounts are also necessary (Cash-book, Ledger, Register of Receipts and Issues of Timber, Sales Book, and Stock-Register). In all of these books entries should be made as concisely as possible. And an annual estimate of the anticipated income and expenditure should be made before the end of each year for the following twelve months, and showing the details upon which it is based.

CHAPTER IV.

THE VALUATION OF TIMBER-CROPS AND OF WOODLANDS.

Valuation of woodlands, whether as separate crops of timber or as a whole, is made by means of formulæ based upon the general formula for summarising a geometrical progression—

$$S = a \frac{1-r^n}{1-r}.$$

There are various specific formulæ which may be applied in problems affecting the valuation of woodlands, but in practice all calculations are made by means of compound interest tables, as shown on page 151 (Appendix II.). Some of these summarise or calculate the future value of a capital, while others discount or calculate its present value; and others again permute or convert a periodic return into an annual rental.

In forestry valuations, the summarising, discounting, and permutation must all be done by compound interest; and it is best to take 3 per cent as the usual rate of interest. Calculations on this basis usually prove forestry under good management to be profitable; and the larger the area, the greater is generally the profit. By arbitrarily raising or lowering the rate of interest used in calculations very divergent results are obtained (*e.g.*, a plantation costing £5 an acre would at 20 years of age have cost £9.03 at 3 per cent, and £10.95 at 5 per cent), and the difference is, of course, all the greater when long periods of years are being dealt with.

The capital in forestry, consisting of *the land + the growing-stock*, which combined form the *woodlands*, may be valued by one or other of four methods:—

1. *Actual cost of production*, so far as concerns the timber-crops ;
2. *Market value*, if sold or compared with similar adjoining properties ;
3. *Its prospective value* as to future net income ; and
4. *Its capitalised value* estimated on the average annual net income (where $C = 100 \times \text{net annual income} \div \text{rate } \%$).

When it is desired to compare the present and the prospective net yield of any two mature or maturing timber-crops, the *indicating percentage* (see p. 102) is a simple formula for practical use.

In all calculations *net income* has to be taken—*i.e.*, gross income less all charges for felling, logging, extracting, &c. ; and it is only by thus applying strictly actuarial methods of calculation that approximately correct estimates can be made. And to be quite correct, all marketable minor produce, shooting, fishing, &c., should be taken into account as well as timber, and due allowance made for the annual outlay on management, planting, upkeep of roads, rates and taxes, &c.

In the Valuation of the Land for Rating, &c., the land, and not the timber-crop, is assessed. In Scotland the estimated annual rental value of highwoods or coppices is taken as the rent the land in its natural unimproved condition might reasonably be expected to fetch if let for pasture or grazing. Under English law, the standard prescribed is practically much the same, being based on the agricultural value of land in its “natural and unimproved” state ; and in the Rating of Plantations, Woods, &c., it is the land, and not the timber, underwood, or other produce of the land, which is made the subject of assessment ; and if the land used as a plantation or a wood, or for the growth of saleable underwood, is subject to common rights, it is exempt from the poor rate and other local rates.

The method of estimating the gross estimated rental and rateable value of such woodlands is prescribed as follows :—

“(a) If the land is used only for a plantation or a wood, the value shall be estimated as if the land instead of being a plantation or a wood were let and occupied in its natural and unimproved state ; (b) if the land is used for the growth of saleable underwood, the value shall be estimated as if the land were let for that purpose ; (c) if the land is used both for a plantation or a wood and for the growth of saleable underwood, the value shall be estimated either as if the land were used only for a plantation or a wood, or as if the land were used only for the growth of the saleable underwood growing thereon as the assessment committee may determine.”

In Valuing Woodlands for Succession Duty the custom has generally been to value all the timber and other wood, and to take 3 per cent of this as a fair annual return from their capital value under good management. This income is then treated as an annuity, and succession duty has to be paid upon it on a scale laid down in tables annexed to the Act. Thus, if the life-tenant were 40 years of age on entering into succession, and the annual income from the woods were estimated at £500 a-year, this annuity would be considered as having a capital value of £7437½ assessable to duty (and not as $£500 \div 0.03 = £16,666$).

The Valuation of a Growing Timber-Crop.—If of marketable size, the present market value of single trees and of the whole crop in any compartment may easily be determined by measurement—or in the case of ornamental trees or groups of trees, by making a fair allowance for their special ornamental value. If only comparatively young immature crops of wood, it will usually be best to estimate their value for sale or transfer according to their total cost up to the present. But deductions must be made for the rental value of the land and general annual charges, in order to arrive at the true value of the timber-crop alone.

The Valuation of the Normal Capital in Wood throughout a Working-Circle.—If the woods forming a working-circle are

in a normal condition, capable of yielding a regular annual fall of equal amount, then there will be a regular gradation of age-classes normally distributed throughout the woodlands and varying from 1 to n years (just before the annual fall) or from 0 to $n - 1$ years of age (just after the fall), n being the rotation with which the woods are worked. It is therefore of advantage to estimate the money value of the normal capital in wood so as to know the rate of interest actually yielded by the working-circle.

For example, say the normal annual returns from a working-circle of 800 acres in normal condition, worked with a rotation of 80 years, consist of £2400 for the mature fall of timber, and £300 from thinnings in woods of different ages, that each year the cost of planting the area cleared is £40, and that the gross general charges amount annually to £160; what is the present value of the Normal Capital in Wood, if the annual rental value of the land is 10s. an acre, and the rate of interest be 3 per cent? Here the net receipts are $2700 - 200 = £2500$, and their capitalised value is $\frac{2500}{0.03} = £83,333\frac{1}{3}$. The rental value of the land being £400 a-year, its capital value is $\frac{400}{0.03} = £13,333\frac{1}{3}$. Hence the capital value of the Normal Capital in Wood is $83,333\frac{1}{3} - 13,333\frac{1}{3} = £70,000$.

The "normal condition" being always a mere ideal, when a valuation of woodlands is made it must necessarily be that of the actual growing-stock or capital in wood. It is only by making such a valuation that the actual rate of interest obtained on the capital invested in the woodlands can be ascertained.

The Net Income obtained from Woodlands may be calculated by the formula $\frac{F + Ta + Tb. + Tq - (c + fv)}{f}$, where

F = the value of the yield of timber obtained at the **final clearance**.

$T(a, b, q)$ = the value of **thinnings** carried out in the years a, b, q, calculated at compound interest up to the date of the final clearance.

c = the outlay for **cultural costs**, calculated at compound interest.

v = the **various annual outlays**, *e.g.*, protection, rates, &c., calculated at compound interest.

f = the number of years included in the **fall or period of rotation of the crop**.

But it is simpler to deduct from the gross income all charges incurred, and to take the mean for several years.

With a regularly sustained annual yield under good management, the woods forming a working-circle of x acres give an annual return in the mature fall *plus* all the thinnings at various ages, as also in minor produce, less cost of reproduction and of general charges, so that the net annual income per acre will be found by dividing the total net income by x .

As this includes the net income from the capital in growing-stock *plus* land, the result obtained cannot be used in comparing the profit of forestry with that of agriculture. It merely shows the net income, but gives no indication as to this being as profitable as it ought to be for the given land.

But the most profitable Rotation—*i.e.*, the rotation which will probably yield the highest percentage on the capital value of the woodland as estimated by the *net* monetary value of its produce—is found by making various calculations, each as if for a single crop, in accordance with the following **formula** (the same rate of interest being used in each case, of course), and ascertaining the rotation showing the greatest profit by indicating the maximum productivity or largest capital value for land and growing stock (Faustmann's formula):—

The productivity of the woodlands (as estimated by the net value of the-timber crop, &c.) is=

$$\frac{F_n + (T_a \times 1.0 p^{n-a}) + (T_b \times 1.0 p^{n-b}) + \dots + (T_q \times 1.0 p^{n-q}) - (c \times 1.0 p^n)}{1.0 p^n - 1} - \frac{g}{0.0p}$$

Where—

F_n =the net income, free from cost of harvesting, yielded by the mature fall at the year n .

$T_a, T_b \dots T_q$ =the net income, free from cost of harvesting, yielded by the thinnings at the years $a, b \dots q$.

p =the percentage or rate of interest which the woodlands are supposed to yield annually on the investment represented by their capital value.

c =the cost of forming the crop originally, or of regenerating or replanting the area on the fall of the mature crop.

g =the annual outlay for general charges (supervision, protection, rates and taxes).

If misused, however, this formula leads to absurd results, for the land and the growing-stock can be shown as having less than no value, if the rotations for which the calculations are made are so low that the produce is unmarketable and fails to counterbalance the cost of planting and upkeep, &c. And the same happens if the rate of interest be high.

For example, if a landowner has land suited for planting mixed Conifer crops, and he wishes to estimate whether a rotation of 80 or 100 years may be most profitable, he could reckon somewhat as follows with whatever data he may think most reliable:—

1. *Immediate Returns (Thinnings).*—Thinnings at 40 years worth £4, at 50 years £5, at 60 years £6, at 70 years £7, at 80 years £8, and at 90 years £9.

2. *Final Yield (Mature Fall).*—Clear-felling at 80 years of age, £183; or at 100 years, £266.

The cost of planting being £5 an acre, the general charges for supervision, protection, and rates and taxes annually amounting to 5s. an acre, and the rate of interest [being taken as 3 per cent, which would prove the more profitable rotation?

(1) For the 80-years' rotation, the present value of the ultimate income from all these future returns is—

$$\begin{aligned}
 &= \frac{183 + (4 \times 1.03^{40}) + (5 \times 1.03^{50}) + (6 \times 1.03^{60}) + (7 \times 1.03^{70}) - (5 \times 1.03^{80})}{1.03^{80} - 1} - \frac{0.25}{0.03} \\
 &= \left[\frac{(183 + 13.0480 + 12.1365 + 10.8366 + 9.4073) - 53.2045}{9.64} \right] - 8.33 \\
 &= \frac{175.22}{9.64} - 8.33 = 18.17 - 8.33 = 9.84 = \text{£}9, 16\text{s. } 9\text{d. per acre.}
 \end{aligned}$$

(2) For the 100 years' rotation it would be—

$$\begin{aligned}
 &= \left\{ \frac{266 + (4 \times 1.03^{60}) + (5 \times 1.03^{50}) + (6 \times 1.03^{40}) + (7 \times 1.03^{30}) + (8 \times 1.03^{20})}{+ (9 \times 1.03^{10}) - (5 \times 1.03^{100})} \right\} - \frac{0.25}{0.03} \\
 &= \left[\frac{(266 + 23.5664 + 21.9195 + 19.5720 + 16.9911 + 14.4488 + 12.0951) - 96.0930}{18.22} \right] - 8.33 \\
 &= \frac{278.50}{18.22} - 8.33 = 15.28 - 8.33 = 6.95 = \text{£}6, 19\text{s. per acre.}
 \end{aligned}$$

The 80-years' rotation would therefore be the more profitable—quite apart from its involving less capital and giving an earlier return from the mature crop.

Another example of this method of calculation may also be given, to show its use for practical purposes. Suppose a Conifer working-circle of

Larch and Scots Pine is worked for pitwood with the following results:—

First thinning at 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 at 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 acre, while wire-fencing against rabbits is fortunately not necessary.

The apparent profit is here—

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

This apparent profit represents a gain of 11s. 2d. per acre per annum 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. But it presumes that no outlay is needed in beating up blanks, that the income from all the thinnings and the final clearance are *net* returns, that the replanting of the land can take place immediately after the mature crop is cleared, that no weeding is needed before the first thinning, and that the annual shooting value covers the rates and taxes, &c.; and it does not include the cost of supervision, tending, repair and upkeep of fences, or contingent expenses of any sort. It is, therefore, ~~not~~ a trustworthy calculation, though as fair as can be made with the data available.

APPENDIX I.—CUBIC CONTENTS OF ROUND LOGS = Length $\times$ $\left(\frac{\text{Mean Girth}}{4}\right)^2$,
in Cubic Feet and Decimals of 1 Cubic Foot.

Length in feet.	MEAN GIRTH IN FEET AND INCHES.											
	3'	3'.1"	3'.2"	3'.3"	3'.4"	3'.5"	3'.6"	3'.7"	3'.8"	3'.9"	3'.10"	3'.11"
10	5.6	5.9	6.3	6.6	6.9	7.3	7.7	8.0	8.4	8.8	9.2	9.6
11	6.2	6.5	6.9	7.3	7.6	8.0	8.4	8.8	9.2	9.7	10.1	10.5
12	6.8	7.1	7.5	7.9	8.3	8.8	9.2	9.6	10.1	10.5	11.0	11.5
13	7.3	7.7	8.1	8.6	9.0	9.5	10.0	10.4	10.9	11.4	11.9	12.5
14	7.9	8.3	8.8	9.2	9.7	10.2	10.7	11.2	11.8	12.3	12.9	13.4
15	8.4	8.9	9.4	9.9	10.4	10.9	11.5	12.0	12.6	13.2	13.8	14.4
16	9.0	9.5	10.0	10.6	11.1	11.7	12.2	12.8	13.4	14.1	14.7	15.3
17	9.6	10.1	10.7	11.2	11.8	12.4	13.0	13.6	14.3	14.9	15.6	16.3
18	10.1	10.7	11.3	11.9	12.5	13.1	13.8	14.4	15.1	15.8	16.5	17.3
19	10.7	11.3	11.9	12.5	13.2	13.9	14.5	15.2	16.0	16.7	17.4	18.2
20	11.3	11.9	12.5	13.2	13.9	14.6	15.3	16.1	16.8	17.6	18.4	19.2
21	11.8	12.5	13.2	13.8	14.6	15.3	16.1	16.9	17.6	18.5	19.3	20.1
22	12.4	13.1	13.8	14.5	15.3	16.1	16.8	17.7	18.5	19.3	20.2	21.1
23	12.9	13.7	14.4	15.2	16.0	16.8	17.6	18.5	19.3	20.2	21.1	22.1
24	13.5	14.3	15.0	15.8	16.7	17.5	18.4	19.3	20.2	21.1	22.0	23.0
25	14.1	14.9	15.7	16.5	17.4	18.2	19.1	20.1	21.0	22.0	23.0	24.0
26	14.6	15.4	16.3	17.2	18.1	19.1	19.9	20.9	21.8	22.9	23.9	24.9
27	15.2	16.0	16.9	17.8	18.7	19.7	20.7	21.7	22.7	23.7	24.8	25.9
28	15.8	16.6	17.5	18.5	19.4	20.4	21.4	22.5	23.5	24.6	25.7	26.8
29	16.3	17.2	18.2	19.1	20.1	21.2	22.2	23.3	24.4	25.5	26.6	27.8
30	16.9	17.8	18.8	19.8	20.8	21.9	23.0	24.1	25.2	26.4	27.6	28.8
	4'	4'.1"	4'.2"	4'.3"	4'.4"	4'.5"	4'.6"	4'.7"	4'.8"	4'.9"	4'.10"	4'.11"
10	10.0	10.4	10.9	11.3	11.7	12.2	12.7	13.1	13.6	14.1	14.6	15.1
11	11.0	11.5	11.9	12.4	12.9	13.4	13.9	14.4	15.0	15.5	16.1	16.6
12	12.0	12.5	13.0	13.5	14.1	14.6	15.2	15.8	16.3	16.9	17.5	18.1
13	13.0	13.5	14.1	14.7	15.3	15.8	16.5	17.1	17.7	18.3	19.0	19.6
14	14.0	14.6	15.2	15.8	16.4	17.1	17.7	18.4	19.1	19.7	20.4	21.2
15	15.0	15.6	16.3	16.9	17.6	18.3	19.0	19.7	20.4	21.2	21.9	22.7
16	16.0	16.7	17.4	18.1	18.8	19.5	20.2	21.0	21.8	22.6	23.4	24.2
17	17.0	17.7	18.4	19.2	20.0	20.7	21.5	22.3	23.1	24.0	24.8	25.7
18	18.0	18.8	19.5	20.3	21.1	21.9	22.8	23.6	24.5	25.4	26.3	27.2
19	19.0	19.8	20.6	21.4	22.3	23.2	24.0	24.9	25.9	26.8	27.7	28.7
20	20.0	20.8	21.7	22.6	23.5	24.4	25.3	26.3	27.2	28.2	29.2	30.2
21	21.0	22.9	22.8	23.7	24.6	25.6	26.6	27.6	28.6	29.6	30.7	31.7
22	22.0	22.9	23.9	24.8	25.8	26.8	27.8	28.9	29.9	31.0	32.1	33.2
23	23.0	24.0	25.0	26.0	27.0	28.0	29.1	30.2	31.3	32.4	33.6	34.7
24	24.0	25.0	26.0	27.1	28.2	29.3	30.4	31.5	32.7	33.8	35.0	36.3
25	25.9	26.1	27.1	28.2	29.3	30.5	31.6	32.8	34.0	35.3	36.5	37.8
26	26.0	27.1	28.2	29.4	30.5	31.7	32.9	34.1	35.4	36.7	38.0	39.3
27	27.0	28.1	29.3	30.5	31.7	32.9	34.2	35.4	36.7	38.1	39.4	40.8
28	28.0	29.2	30.4	31.6	32.9	34.1	35.4	36.8	38.1	39.5	40.9	42.3
29	29.0	30.2	31.5	32.7	34.0	35.4	36.7	38.1	39.5	40.9	42.3	43.8
30	30.0	31.3	32.6	33.9	35.2	36.6	38.0	39.4	40.8	42.3	43.8	45.3

APPENDIX I. (continued)—CUBIC CONTENTS OF ROUND LOGS = Length $\times$ $\left(\frac{\text{Mean Girth}}{4}\right)$
in Cubic Feet and Decimals of 1 Cubic Foot.

Length in feet.	MEAN GIRTH IN FEET AND INCHES.											
	5'	5'1"	5'2"	5'3"	5'4"	5'5"	5'6"	5'7"	5'8"	5'9"	5'10"	5'11"
10	15·6	16·2	16·7	17·2	17·8	18·3	18·9	19·5	20·1	20·7	21·3	21·
11	17·2	17·8	18·4	18·9	19·6	20·2	20·8	21·4	22·1	22·7	23·4	24·
12	18·8	19·4	20·0	20·7	21·3	22·0	22·7	23·4	24·1	24·8	25·5	26·
13	20·3	21·0	21·7	22·4	23·1	23·8	24·6	25·3	26·1	26·9	27·6	28·
14	21·9	22·6	23·4	24·1	24·9	25·7	26·5	27·3	28·1	28·9	29·8	30·
15	23·4	24·2	25·0	25·8	26·7	27·5	28·4	29·2	30·1	31·0	31·9	32·
16	25·0	25·8	26·7	27·6	28·4	29·3	30·2	31·2	32·1	33·1	34·0	35·
17	26·6	27·5	28·4	29·3	30·2	31·2	32·1	33·1	34·1	35·1	36·2	37·
18	28·1	29·1	30·0	31·0	32·0	33·0	34·0	35·1	36·1	37·2	38·3	39·
19	29·7	30·7	31·7	32·7	33·8	34·8	35·9	37·0	38·1	39·3	40·4	41·
20	31·3	32·3	33·4	34·5	35·6	36·7	37·8	39·0	40·1	41·3	42·5	43·
21	32·8	33·9	35·0	36·2	37·3	38·5	39·7	40·9	42·1	43·4	44·7	45·
22	34·4	35·5	36·7	37·9	39·1	40·3	41·6	42·9	44·2	45·5	46·8	48·
23	35·9	37·1	38·4	39·6	40·9	42·2	43·5	44·8	46·2	47·5	48·9	50·
24	37·5	38·8	40·0	41·3	42·7	44·0	45·4	46·8	48·2	49·6	51·0	52·
25	39·1	40·4	41·7	43·1	44·4	45·8	47·3	48·7	50·2	51·7	53·2	54·
26	40·6	42·0	43·4	44·8	46·2	47·7	49·2	50·7	52·2	53·7	55·3	56·
27	42·2	43·6	45·0	46·5	48·9	49·5	51·0	52·6	54·2	55·8	57·4	59·
28	43·8	45·2	46·7	48·2	49·8	51·3	52·9	54·6	56·2	57·9	59·5	61·
29	45·3	46·8	48·4	50·0	51·6	53·2	54·8	56·5	58·2	59·9	61·7	63·
30	46·9	48·5	50·1	51·7	53·3	55·0	56·7	58·5	60·2	62·0	63·8	65·
	6'	6'1"	6'2"	6'3"	6'4"	6'5"	6'6"	6'7"	6'8"	6'9"	6'10"	6'11"
10	22·5	23·1	23·8	24·4	25·1	25·7	26·4	27·1	27·8	28·5	29·2	29·
11	24·8	25·4	26·1	26·9	27·6	28·3	29·0	29·8	30·6	31·3	32·1	32·
12	27·0	27·8	28·5	29·3	30·1	30·9	31·7	32·5	33·3	34·2	35·0	35·
13	29·3	30·1	30·9	31·7	32·6	33·5	34·3	35·2	36·1	37·0	37·9	38·
14	31·5	32·4	33·3	34·2	35·1	36·0	37·0	37·9	38·9	39·9	40·9	41·
15	33·8	34·7	35·7	36·6	37·6	38·6	39·6	40·6	41·7	42·7	43·8	44·
16	36·0	37·0	38·0	39·1	40·1	41·2	42·2	43·3	44·4	45·6	46·7	47·
17	38·3	39·3	40·4	41·5	42·6	43·7	44·9	46·0	47·2	48·4	49·6	50·
18	40·5	41·6	42·8	43·9	45·1	46·3	47·5	48·8	50·0	51·3	52·5	53·
19	42·8	43·9	45·2	46·4	47·6	48·9	50·2	51·5	52·8	54·1	55·4	56·
20	45·0	46·3	47·5	48·8	50·1	51·5	52·8	54·2	55·6	57·0	58·4	59·
21	47·3	48·6	49·9	51·3	52·6	54·0	55·5	56·9	58·3	59·8	61·3	62·
22	49·5	50·9	52·3	53·7	55·2	56·6	58·1	59·6	61·1	62·6	64·2	65·
23	51·8	53·2	54·7	56·2	57·7	59·2	60·7	62·3	63·9	65·5	67·1	68·
24	54·0	55·5	57·0	58·6	60·2	61·8	63·4	65·0	66·7	68·3	70·0	71·
25	56·3	57·8	59·4	61·0	62·7	64·3	66·0	67·7	69·4	71·2	73·0	74·
26	58·5	60·1	61·8	63·5	65·2	66·9	68·7	70·4	72·2	74·0	75·9	77·
27	60·8	62·4	64·2	65·9	67·7	69·5	71·3	73·1	75·0	76·9	78·8	80·
28	63·0	64·8	66·5	68·4	70·2	72·1	73·9	75·8	77·8	79·7	81·7	83·
29	65·3	67·1	68·9	70·8	72·7	74·6	76·6	78·6	80·6	82·6	84·6	86·
30	67·5	69·4	71·3	73·2	75·2	77·2	79·2	81·3	83·3	85·4	87·6	89·

APPENDIX I. (continued).—CUBIC CONTENTS OF ROUND LOGS = Length $\times$ $\left(\frac{\text{Mean Girth}}{4}\right)^2$,
in Cubic Feet and Decimals of 1 Cubic Foot.

Length in feet.	MEAN GIRTH IN FEET AND INCHES.											
	7'	7'.1"	7'.2"	7'.3"	7'.4"	7'.5"	7'.6"	7'.7"	7'.8"	7'.9"	7'.10"	7'.11"
10	30.6	31.4	32.1	32.9	33.6	34.4	35.2	35.9	36.7	37.5	38.4	39.2
11	33.7	34.5	35.3	36.1	37.0	37.8	38.7	39.5	40.4	41.3	42.2	43.1
12	36.8	37.6	38.5	39.4	40.3	41.3	42.2	43.1	44.1	45.0	46.0	47.0
13	39.8	40.8	41.7	42.7	43.7	44.7	45.7	46.7	47.8	48.8	49.9	50.9
14	42.9	43.9	44.9	46.0	47.1	48.1	49.2	50.3	51.4	52.6	53.7	54.8
15	45.9	47.0	48.2	49.3	50.4	51.6	52.7	53.9	55.1	56.3	57.5	58.8
16	49.0	50.2	51.4	52.6	53.8	55.0	56.2	57.5	58.8	60.1	61.4	62.7
17	52.1	53.3	54.6	55.8	57.1	58.4	59.8	61.1	62.5	63.8	65.2	66.6
18	55.1	56.4	57.8	59.1	60.5	61.9	63.3	64.7	66.1	67.6	69.0	70.5
19	58.2	59.6	61.0	62.4	63.9	65.3	66.8	68.3	69.8	71.3	72.9	74.4
20	61.3	62.7	64.2	65.7	67.2	68.8	70.3	71.9	73.5	75.1	76.7	78.3
21	64.3	65.9	67.4	69.0	70.6	72.2	73.8	75.5	77.1	78.8	80.5	82.3
22	67.4	69.0	70.6	72.3	73.9	75.6	77.3	79.1	80.8	82.6	84.4	86.2
23	70.4	72.1	73.8	75.6	77.3	79.1	80.9	82.7	84.5	86.3	88.2	90.1
24	73.5	75.3	77.0	78.8	80.7	82.5	84.4	86.3	88.2	90.1	92.0	94.0
25	76.6	78.4	80.3	82.1	83.0	85.9	87.9	89.9	91.8	93.8	95.9	97.9
26	79.6	81.5	83.5	85.5	87.4	89.4	91.4	93.4	95.5	97.6	99.7	101.8
27	82.7	84.7	86.7	88.7	90.7	92.8	94.9	97.0	99.2	101.4	103.5	105.8
28	85.8	87.8	89.9	92.0	94.1	96.3	98.4	100.6	102.9	105.1	107.4	109.7
29	88.8	90.9	93.1	95.3	97.5	99.7	102.0	104.2	106.5	108.9	111.2	113.6
30	91.9	94.1	96.3	98.6	100.8	103.1	105.5	107.8	110.2	112.6	115.1	117.5
31	95.0	97.3	99.6	101.9	104.2	106.5	108.8	111.1	113.5	115.9	118.3	120.7
32	98.1	100.5	102.9	105.3	107.7	110.1	112.5	114.9	117.3	119.7	122.1	124.5
33	101.2	103.6	106.0	108.4	110.8	113.2	115.6	118.0	120.4	122.8	125.2	127.6
34	104.3	106.7	109.1	111.5	113.9	116.3	118.7	121.1	123.5	125.9	128.3	130.7
35	107.4	109.8	112.2	114.6	117.0	119.4	121.8	124.2	126.6	129.0	131.4	133.8
36	110.5	112.9	115.3	117.7	120.1	122.5	124.9	127.3	129.7	132.1	134.5	136.9
37	113.6	116.0	118.4	120.8	123.2	125.6	128.0	130.4	132.8	135.2	137.6	140.0
38	116.7	119.1	121.5	123.9	126.3	128.7	131.1	133.5	135.9	138.3	140.7	143.1
39	119.8	122.2	124.6	127.0	129.4	131.8	134.2	136.6	139.0	141.4	143.8	146.2
40	122.9	125.3	127.7	130.1	132.5	134.9	137.3	139.7	142.1	144.5	146.9	149.3
41	126.0	128.4	130.8	133.2	135.6	138.0	140.4	142.8	145.2	147.6	150.0	152.4
42	129.1	131.5	133.9	136.3	138.7	141.1	143.5	145.9	148.3	150.7	153.1	155.5
43	132.2	134.6	137.0	139.4	141.8	144.2	146.6	149.0	151.4	153.8	156.2	158.6
44	135.3	137.7	140.1	142.5	144.9	147.3	149.7	152.1	154.5	156.9	159.3	161.7
45	138.4	140.8	143.2	145.6	148.0	150.4	152.8	155.2	157.6	160.0	162.4	164.8
46	141.5	143.9	146.3	148.7	151.1	153.5	155.9	158.3	160.7	163.1	165.5	167.9
47	144.6	147.0	149.4	151.8	154.2	156.6	159.0	161.4	163.8	166.2	168.6	171.0
48	147.7	150.1	152.5	154.9	157.3	159.7	162.1	164.5	166.9	169.3	171.7	174.1
49	150.8	153.2	155.6	158.0	160.4	162.8	165.2	167.6	170.0	172.4	174.8	177.2
50	153.9	156.3	158.7	161.1	163.5	165.9	168.3	170.7	173.1	175.5	177.9	180.3
51	157.0	159.4	161.8	164.2	166.6	169.0	171.4	173.8	176.2	178.6	181.0	183.4
52	160.1	162.5	164.9	167.3	169.7	172.1	174.5	176.9	179.3	181.7	184.1	186.5
53	163.2	165.6	168.0	170.4	172.8	175.2	177.6	180.0	182.4	184.8	187.2	189.6
54	166.3	168.7	171.1	173.5	175.9	178.3	180.7	183.1	185.5	187.9	190.3	192.7
55	169.4	171.8	174.2	176.6	179.0	181.4	183.8	186.2	188.6	191.0	193.4	195.8
56	172.5	174.9	177.3	179.7	182.1	184.5	186.9	189.3	191.7	194.1	196.5	198.9
57	175.6	178.0	180.4	182.8	185.2	187.6	190.0	192.4	194.8	197.2	199.6	202.0
58	178.7	181.1	183.5	185.9	188.3	190.7	193.1	195.5	197.9	200.3	202.7	205.1
59	181.8	184.2	186.6	189.0	191.4	193.8	196.2	198.6	201.0	203.4	205.8	208.2
60	184.9	187.3	189.7	192.1	194.5	196.9	199.3	201.7	204.1	206.5	208.9	211.3
61	188.0	190.4	192.8	195.2	197.6	200.0	202.4	204.8	207.2	209.6	212.0	214.4
62	191.1	193.5	195.9	198.3	200.7	203.1	205.5	207.9	210.3	212.7	215.1	217.5
63	194.2	196.6	199.0	201.4	203.8	206.2	208.6	211.0	213.4	215.8	218.2	220.6
64	197.3	199.7	202.1	204.5	206.9	209.3	211.7	214.1	216.5	218.9	221.3	223.7
65	200.4	202.8	205.2	207.6	210.0	212.4	214.8	217.2	219.6	222.0	224.4	226.8
66	203.5	205.9	208.3	210.7	213.1	215.5	217.9	220.3	222.7	225.1	227.5	229.9
67	206.6	209.0	211.4	213.8	216.2	218.6	221.0	223.4	225.8	228.2	230.6	233.0
68	209.7	212.1	214.5	216.9	219.3	221.7	224.1	226.5	228.9	231.3	233.7	236.1
69	212.8	215.2	217.6	220.0	222.4	224.8	227.2	229.6	232.0	234.4	236.8	239.2
70	215.9	218.3	220.7	223.1	225.5	227.9	230.3	232.7	235.1	237.5	239.9	242.3
71	219.0	221.4	223.8	226.2	228.6	231.0	233.4	235.8	238.2	240.6	243.0	245.4
72	222.1	224.5	226.9	229.3	231.7	234.1	236.5	238.9	241.3	243.7	246.1	248.5
73	225.2	227.6	230.0	232.4	234.8	237.2	239.6	242.0	244.4	246.8	249.2	251.6
74	228.3	230.7	233.1	235.5	237.9	240.3	242.7	245.1	247.5	249.9	252.3	254.7
75	231.4	233.8	236.2	238.6	241.0	243.4	245.8	248.2	250.6	253.0	255.4	257.8
76	234.5	236.9	239.3	241.7	244.1	246.5	248.9	251.3	253.7	256.1	258.5	260.9
77	237.6	240.0	242.4	244.8	247.2	249.6	252.0	254.4	256.8	259.2	261.6	264.0
78	240.7	243.1	245.5	247.9	250.3	252.7	255.1	257.5	259.9	262.3	264.7	267.1
79	243.8	246.2	248.6	251.0	253.4	255.8	258.2	260.6	263.0	265.4	267.8	270.2
80	246.9	249.3	251.7	254.1	256.5	258.9	261.3	263.7	266.1	268.5	270.9	273.3
81	250.0	252.4	254.8	257.2	259.6	262.0	264.4	266.8	269.2	271.6	274.0	276.4
82	253.1	255.5	257.9	260.3	262.7	265.1	267.5	269.9	272.3	274.7	277.1	279.5
83	256.2	258.6	261.0	263.4	265.8	268.2	270.6	273.0	275.4	277.8	280.2	282.6
84	259.3	261.7	264.1	266.5	268.9	271.3	273.7	276.1	278.5	280.9	283.3	285.7
85	262.4	264.8	267.2	269.6	272.0	274.4	276.8	279.2	281.6	284.0	286.4	288.8
86	265.5	267.9	270.3	272.7	275.1	277.5	279.9	282.3	284.7	287.1	289.5	291.9
87	268.6	271.0	273.4	275.8	278.2	280.6	283.0	285.4	287.8	290.2	292.6	295.0
88	271.7	274.1	276.5	278.9	281.3	283.7	286.1	288.5	290.9	293.3	295.7	298.1
89	274.8	277.2	279.6	282.0	284.4	286.8	289.2	291.6	294.0	296.4	298.8	301.2
90	277.9	280.3	282.7	285.1	287.5	289.9	292.3	294.7	297.1	299.5	301.9	304.3
91	281.0	283.4	285.8	288.2	290.6	293.0	295.4	297.8	300.2	302.6	305.0	307.4
92	284.1	286.5	288.9	291.3	293.7	296.1	298.5	300.9	303.3	305.7	308.1	310.5
93	287.2	289.6	292.0	294.4	296.8	299.2	301.6	304.0	306.4	308.8	311.2	313.6
94	290.3	292.7	295.1	297.5	299.9	302.3	304.7	307.1	309.5	311.9	314.3	316.7
95	293.4	295.8	298.2	300.6	303.0	305.4	307.8	310.2	312.6	315.0	317.4	319.8
96	296.5	298.9	301.3	303.7	306.1	308.5	310.9	313.3	315.7	318.1	320.5	322.9
97	299.6	302.0	304.4	306.8	309.2	311.6	314.0	316.4	318.8	321.2	323.6	326.0
98	302.7	305.1	307.5	309.9	312.3	314.7	317.1	319.5	321.9	324.3	326.7	329.1
99	305.8	308.2	310.6	313.0	315.4	317.8	320.2	322.6	325.0	327.4	329.8	332.2
100	308.9	311.3	313.7	316.1	318.5	320.9	323.3	325.7	328.1	330.5	332.9	335.3

APPENDIX I. (continued)—CUBIC CONTENTS OF ROUND LOGS = Length $\times$ $\left(\frac{\text{Mean Girth}}{4}\right)^2$,
in Cubic Feet and Decimals of 1 Cubic Foot.

Length in feet.	MEAN GIRTH IN FEET AND INCHES.											
	9'	9'.1"	9'.2"	9'.3"	9'.4"	9'.5"	9'.6"	9'.7"	9'.8"	9'.9"	9'.10"	9'.11"
10	50.6	51.6	52.5	53.5	54.4	55.4	56.4	57.4	58.4	59.4	60.4	61.5
11	55.7	56.7	57.8	58.8	59.9	61.0	62.0	63.1	64.2	65.4	66.5	67.6
12	60.8	61.9	63.0	64.2	65.3	66.5	67.7	68.9	70.1	71.3	72.5	73.8
13	65.8	67.0	68.3	69.5	70.8	72.0	73.3	74.6	75.9	77.2	78.6	79.9
14	70.9	72.2	73.5	74.9	76.2	77.6	79.0	80.4	81.8	83.2	84.6	86.0
15	75.9	77.4	78.8	80.2	81.7	83.1	84.6	86.1	87.6	89.1	90.7	92.2
16	81.0	82.5	84.0	85.6	87.1	88.7	90.2	91.8	93.4	95.1	96.7	98.3
17	86.1	87.7	89.3	90.9	92.6	94.2	95.9	97.6	99.3	101.0	102.7	104.5
18	91.1	92.8	94.5	96.3	98.0	99.8	101.5	103.3	105.1	106.9	108.8	110.6
19	96.2	98.0	99.8	101.6	103.4	105.3	107.2	109.1	111.0	112.9	114.8	116.8
20	101.3	103.1	105.0	107.0	108.9	110.8	112.8	114.8	116.8	118.8	120.9	122.9
21	106.3	108.3	110.3	112.3	114.3	116.4	118.5	120.5	122.6	124.8	126.9	129.1
22	111.4	113.4	115.5	117.6	119.8	121.9	124.1	126.3	128.5	130.7	133.0	135.2
23	116.4	118.6	120.8	123.0	125.2	127.5	129.7	132.0	134.3	136.7	139.0	141.4
24	121.5	123.8	126.0	128.3	130.7	133.0	135.4	137.8	140.2	142.6	145.0	147.5
25	126.6	128.9	131.3	133.7	136.1	138.6	141.0	143.5	146.0	148.5	151.1	153.7
26	131.6	134.1	136.5	139.0	141.6	144.1	146.7	149.2	151.8	154.5	157.1	159.8
27	136.7	139.2	141.8	144.4	147.0	149.6	152.3	155.0	157.7	160.4	163.2	165.9
28	141.8	144.4	147.0	149.7	152.4	155.2	157.9	160.7	163.5	166.4	169.2	172.1
29	146.8	149.5	152.3	155.1	157.9	160.7	163.6	166.5	169.4	172.3	175.3	178.2
30	151.9	154.7	157.6	160.4	163.3	166.3	169.2	172.2	175.2	178.2	181.3	184.4
10'	10'.1"	10'.2"	10'.3"	10'.4"	10'.5"	10'.6"	10'.7"	10'.8"	10'.9"	10'.10"	10'.11"	
10	62.5	63.5	64.6	65.7	66.7	67.8	68.9	70.0	71.1	72.2	73.4	74.6
11	68.8	69.9	71.1	72.2	73.4	74.6	75.8	77.0	78.2	79.4	80.7	81.9
12	75.0	76.3	77.5	78.8	80.1	81.4	82.7	84.0	85.3	86.7	88.0	89.4
13	81.3	82.6	84.0	85.4	86.8	88.2	89.6	91.0	92.4	93.9	95.4	96.8
14	87.5	89.0	90.4	91.9	93.4	94.9	96.5	98.0	99.6	101.1	102.7	104.3
15	93.8	95.3	96.9	98.5	100.1	101.7	103.4	105.0	106.7	108.3	110.0	111.7
16	100.0	101.7	103.4	105.1	106.8	108.5	110.2	112.0	113.8	115.6	117.4	119.2
17	106.3	108.0	109.8	111.6	113.5	115.3	117.1	119.0	120.9	122.8	124.7	126.6
18	112.5	113.4	116.3	118.2	120.1	122.1	124.0	126.0	128.0	130.0	132.0	134.1
19	118.8	120.7	122.7	124.8	126.8	128.9	130.9	133.0	135.1	137.2	139.4	141.5
20	125.0	127.1	129.2	131.3	133.5	135.6	137.8	140.0	142.2	144.5	146.7	149.0
21	131.3	133.4	135.7	137.9	140.1	142.4	144.7	147.0	149.3	151.7	154.0	156.4
22	137.5	139.8	142.1	144.5	146.8	149.2	151.6	154.0	156.4	158.9	161.4	163.9
23	143.8	146.2	148.6	151.0	153.5	156.0	158.5	161.0	163.6	166.1	168.7	171.3
24	150.0	152.5	155.0	157.6	160.2	162.8	165.4	168.0	170.7	173.3	176.0	178.8
25	156.3	158.9	161.5	164.2	166.8	169.5	172.3	175.0	177.8	180.6	183.4	186.2
26	162.5	165.2	168.8	170.7	173.5	176.3	179.2	182.0	184.9	187.8	190.7	193.7
27	168.8	171.6	174.4	177.3	180.2	183.1	186.0	189.0	192.0	195.0	198.0	201.1
28	175.0	177.9	180.9	183.9	186.9	189.9	192.9	196.0	199.1	202.2	205.4	208.6
29	181.3	184.3	187.3	190.4	193.5	196.7	199.8	203.0	206.2	209.5	212.7	216.0
30	187.5	190.6	193.8	197.0	200.2	203.5	206.7	210.0	213.3	216.7	220.1	223.5

APPENDIX II.—TABLES OF COMPOUND INTEREST AND DISCOUNT.

Examples of the Use of the Tables :—

Table I.—A capital of 1 at 3 per cent in twenty years becomes 1·8061 ; therefore £100 would become $100 \times 1\cdot8061 = 180\cdot61 = \text{£}180, 12\text{s. } 2\text{d.}$

„ II.—A capital of 1 obtainable in 40 years has, at 3 per cent, a present value of only 0·3066 ; therefore £100 would only have a present value of $100 \times 0\cdot3066 = 30\cdot66 = \text{£}30, 13\text{s. } 2\text{d.}$

„ III.—A return of 1 due 10 years hence, and every 10 years after that, has at 4 per cent a present value of 2·0823 ; therefore a similar return of £20 (as, for example, the net income from a piece of coppice cut every 10 years) would have a present value of $20 \times 2\cdot0823 = 41\cdot646 = \text{£}41, 12\text{s. } 11\text{d.}$

„ IV.—A return of 1 obtainable for the next 20 years represents, at 3 per cent interest, 26·8704 at the end of that time ; therefore a hunt leasing a piece of woodland as a fox-covert for 20 years at a rental of £20 a-year, will by the end of that time have paid a sum equal to $20 \times 26\cdot8704 = 537\cdot408 = \text{£}537, 8\text{s. } 2\text{d.}$

And conversely, this table can be used to ascertain the annual payment necessary to establish a Fund which will amount to a certain sum in n years, through dividing the capital by the final value

$$(r = \frac{C}{1\cdot0 p^n - 1} \times 0\cdot0 p).$$

For example, if £5000 are payable 20 years hence, what sum must be invested annually at 3 per cent to form a fund that will clear the debt then ? Here $r = 5000 \div 26\cdot8704 = 186\cdot07 = \text{£}186, 1\text{s. } 5\text{d.}$

„ V.—An annual return of 1 obtainable for the next 20 years has, at 3 per cent interest, a present value of 14·8775 ; therefore a rental of £20 a-year payable by a hunt leasing a wood for 20 years as a fox-covert would, at 3 per cent, be equal to a present total payment of $20 \times 14\cdot8775 = 297\cdot55 = \text{£}297, 11\text{s.}$

And conversely, the annual sum required to liquidate within the course of n years a debt now incurred, is ascertained through dividing this sum by the present value as shown in this table

$$(r = C \times \frac{1\cdot0 p^n \times 0\cdot0 p}{1\cdot0 p^n - 1}).$$

For example, if a debt of £5000 be now incurred, it can, reckoning 3 per cent interest, be gradually liquidated (along with the interest due on it) in 20 years by an annual payment of $r = 5000 \div 14\cdot8775 = 336\cdot077 = \text{£}336, 1\text{s. } 6\text{d.}$

TABLE I.—THE SUMMARISED FUTURE VALUE OF A CAPITAL (C) of 1, accumulating at Compound Interest for n years, the rate of Interest being p . [$C_n = C \times 1.0\ p^n$].

Years. n .	Rate of interest (p) per cent.				
	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$
1	1.0250	1.0300	1.0350	1.0400	1.0450
2	1.0506	1.0609	1.0712	1.0816	1.0920
3	1.0769	1.0927	1.1087	1.1249	1.1412
4	1.1038	1.1255	1.1475	1.1699	1.1925
5	1.1314	1.1593	1.1877	1.2167	1.2462
6	1.1597	1.1941	1.2293	1.2653	1.3023
7	1.1887	1.2299	1.2723	1.3159	1.3609
8	1.2184	1.2668	1.3168	1.3686	1.4221
9	1.2489	1.3048	1.3629	1.4233	1.4861
10	1.2801	1.3439	1.4106	1.4802	1.5530
11	1.3121	1.3842	1.4600	1.5395	1.6229
12	1.3449	1.4258	1.5111	1.6010	1.6959
13	1.3785	1.4685	1.5640	1.6651	1.7722
14	1.4130	1.5126	1.6187	1.7317	1.8519
15	1.4483	1.5580	1.6753	1.8009	1.9353
16	1.4845	1.6047	1.7340	1.8730	2.0224
17	1.5216	1.6528	1.7947	1.9479	2.1134
18	1.5597	1.7024	1.8575	2.0258	2.2085
19	1.5986	1.7535	1.9225	2.1068	2.3079
20	1.6386	1.8061	1.9898	2.1911	2.4117
21	1.6796	1.8603	2.0594	2.2788	2.5202
22	1.7216	1.9161	2.1315	2.3699	2.6337
23	1.7646	1.9736	2.2061	2.4647	2.7522
24	1.8087	2.0328	2.2833	2.5633	2.8760
25	1.8539	2.0938	2.3632	2.6658	3.0054
26	1.9003	2.1566	2.4460	2.7725	3.1407
27	1.9478	2.2213	2.5316	2.8834	3.2820
28	1.9965	2.2879	2.6202	2.9987	3.4297
29	2.0464	2.3566	2.7119	3.1187	3.5840
30	2.0976	2.4273	2.8068	3.2434	3.7453
35	2.3732	2.8139	3.3336	3.9461	4.6673
40	2.6851	3.2620	3.9593	4.8010	5.8164
45	3.0379	3.7816	4.7024	5.8412	7.2482
50	3.4371	4.3839	5.5849	7.1067	9.0326
55	3.8888	5.0821	6.6331	8.6464	11.2563
60	4.3998	5.8916	7.8781	10.5196	14.0274
65	4.9780	6.8300	9.3567	12.7987	17.4807
70	5.6321	7.9178	11.1128	15.5716	21.7841
75	6.3722	9.1789	13.1986	18.9453	26.1470
80	7.2096	10.6409	15.6757	23.0498	33.8301
90	9.2289	14.3005	22.1122	34.1193	52.5371
100	11.8137	19.2186	31.1914	50.5049	81.5885

TABLE II.—THE DISCOUNTED PRESENT VALUE OF A CAPITAL (C_n) of 1, realisable n years hence, the rate of Interest being p . [$C = \frac{C_n}{1.0 p^n}$].

Years. n .	Rate of interest (p) per cent.				
	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$
1	0.9756	0.9709	0.9662	0.9615	0.9569
2	0.9518	0.9426	0.9335	0.9246	0.9157
3	0.9286	0.9151	0.9019	0.8890	0.8763
4	0.9060	0.8885	0.8714	0.8548	0.8386
5	0.8839	0.8626	0.8420	0.8219	0.8025
6	0.8623	0.8375	0.8135	0.7903	0.7679
7	0.8413	0.8131	0.7860	0.7599	0.7348
8	0.8207	0.7894	0.7594	0.7307	0.7032
9	0.8007	0.7664	0.7337	0.7026	0.6729
10	0.7812	0.7441	0.7089	0.6756	0.6439
11	0.7621	0.7224	0.6849	0.6496	0.6162
12	0.7436	0.7014	0.6618	0.6246	0.5897
13	0.7254	0.6810	0.6394	0.6006	0.5643
14	0.7077	0.6611	0.6178	0.5775	0.5400
15	0.6905	0.6419	0.5969	0.5553	0.5167
16	0.6736	0.6232	0.5767	0.5339	0.4945
17	0.6572	0.6050	0.5572	0.5134	0.4732
18	0.6412	0.5874	0.5384	0.4936	0.4528
19	0.6255	0.5703	0.5202	0.4746	0.4333
20	0.6103	0.5537	0.5026	0.4564	0.4146
21	0.5954	0.5375	0.4856	0.4388	0.3968
22	0.5809	0.5219	0.4692	0.4220	0.3797
23	0.5667	0.5067	0.4533	0.4057	0.3633
24	0.5529	0.4919	0.4380	0.3901	0.3477
25	0.5394	0.4776	0.4231	0.3751	0.3327
26	0.5262	0.4637	0.4088	0.3607	0.3184
27	0.5134	0.4502	0.3950	0.3468	0.3047
28	0.5009	0.4371	0.3817	0.3335	0.2916
29	0.4887	0.4243	0.3687	0.3207	0.2790
30	0.4767	0.4120	0.3563	0.3083	0.2670
35	0.4214	0.3554	0.3000	0.2534	0.2143
40	0.3724	0.3066	0.2526	0.2083	0.1719
45	0.3292	0.2644	0.2127	0.1712	0.1380
50	0.2909	0.2281	0.1791	0.1407	0.1107
55	0.2572	0.1968	0.1508	0.1157	0.0888
60	0.2273	0.1697	0.1269	0.0951	0.0713
65	0.2009	0.1464	0.1069	0.0781	0.0572
70	0.1776	0.1263	0.0900	0.0642	0.0459
75	0.1569	0.1089	0.0758	0.0528	0.0368
80	0.1387	0.0940	0.0638	0.0434	0.0296
90	0.1084	0.0699	0.0452	0.0293	0.0190
100	0.0847	0.0520	0.0321	0.0198	0.0123

TABLE III.—THE DISCOUNTED PRESENT VALUE OF A PERPETUAL PERIODIC RENTAL OR RETURN (R) of 1, obtainable every n years, the rate of Interest being p . [$C = \frac{R}{1.0 p^n - 1}$].

Years. n .	Rate of interest (p) per cent.				
	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$
1	40.0000	33.3333	28.5714	25.0000	22.2222
2	19.7531	16.4204	14.0400	12.2549	10.8666
3	13.0055	10.7843	9.1981	8.0087	7.0839
4	9.6327	7.9676	6.7786	5.8873	5.1943
5	7.6099	6.2785	5.3280	4.6157	4.0620
6	6.2620	5.1533	4.3620	3.7690	3.3084
7	5.2998	4.3502	3.6727	3.1652	2.7711
8	4.5787	3.7485	3.1565	2.7132	2.3691
9	4.0183	3.2811	2.7556	2.3623	2.0572
10	3.5703	2.9077	2.4355	2.0823	1.8084
11	3.2042	2.6026	2.1741	1.8537	1.6055
12	2.8995	2.3487	1.9567	1.6638	1.4370
13	2.6419	2.1343	1.7732	1.5036	1.2950
14	2.4215	1.9509	1.6163	1.3667	1.1738
15	2.2307	1.7922	1.4807	1.2485	1.0692
16	2.0640	1.6537	1.3624	1.1455	0.9781
17	1.9171	1.5317	1.2584	1.0550	0.8982
18	1.7868	1.4236	1.1662	0.9748	0.8275
19	1.6704	1.3271	1.0840	0.9035	0.7646
20	1.5659	1.2405	1.0103	0.8395	0.7084
21	1.4715	1.1624	0.9439	0.7820	0.6578
22	1.3859	1.0916	0.8838	0.7300	0.6121
23	1.3079	1.0271	0.8291	0.6827	0.5707
24	1.2365	0.9682	0.7792	0.6397	0.5330
25	1.1710	0.9143	0.7335	0.6003	0.4986
26	1.1107	0.8646	0.6916	0.5642	0.4671
27	1.0551	0.8188	0.6529	0.5310	0.4382
28	1.0035	0.7764	0.6172	0.5003	0.4116
29	0.9556	0.7372	0.5842	0.4720	0.3870
30	0.9111	0.7006	0.5535	0.4458	0.3643
35	0.7282	0.5513	0.4285	0.3394	0.2727
40	0.5934	0.4421	0.3379	0.2631	0.2076
45	0.4907	0.3595	0.2701	0.2066	0.1600
50	0.4103	0.2955	0.2181	0.1638	0.1245
55	0.3462	0.2450	0.1775	0.1308	0.0975
60	0.2941	0.2044	0.1454	0.1050	0.0768
65	0.2514	0.1715	0.1197	0.0848	0.0607
70	0.2159	0.1446	0.0989	0.0686	0.0481
75	0.1861	0.1223	0.0820	0.0557	0.0382
80	0.1610	0.1037	0.0681	0.0454	0.0305
90	0.1215	0.0752	0.0474	0.0302	0.0194
100	0.0925	0.0549	0.0331	0.0202	0.0124

TABLE IV.—THE SUMMARISED FUTURE VALUE OF AN ANNUAL RENTAL OR RETURN (r) of 1, obtainable for n years in all, the rate of Interest being p . $\left[C_n = \frac{r(1 \cdot 0 \ p^n - 1)}{0 \cdot 0p}\right]$.

Years. n .	Rate of interest (p) per cent.				
	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$
1	1·0000	1·0000	1·0000	1·0000	1·0000
2	2·0250	2·0300	2·0350	2·0400	2·0450
3	3·0756	3·0909	3·1062	3·1216	3·1370
4	4·1525	4·1836	4·2149	4·2465	4·2782
5	5·2563	5·3091	5·3625	5·4163	5·4707
6	6·3877	6·4684	6·5502	6·6330	6·7169
7	7·5474	7·6625	7·7794	7·8983	8·0192
8	8·7361	8·8923	9·0517	9·2142	9·3800
9	8·9545	10·1591	10·3685	10·5828	10·8021
10	11·2034	11·4639	11·7314	12·0061	12·2882
11	12·4835	12·8078	13·1420	13·4864	13·8412
12	12·7956	14·1920	14·6020	15·0258	15·4640
13	15·1404	15·6178	16·1130	16·6268	17·1599
14	16·5190	17·0863	17·6770	18·2919	18·9321
15	17·9319	18·5989	19·2957	20·0236	20·7841
16	19·3802	20·1569	20·9710	21·8245	22·7193
17	20·8647	21·7616	22·7050	23·6975	24·7417
18	22·3863	23·4144	24·4997	25·6454	26·8551
19	23·9460	25·1169	26·3572	27·6712	29·0636
20	25·5447	26·8704	28·2797	29·7781	31·3714
21	27·1833	28·6765	30·2695	31·9692	33·7831
22	28·8629	30·5368	32·3289	34·2480	36·3034
23	30·5844	32·4529	34·4604	36·6179	38·9370
24	32·3490	34·4265	36·6665	39·0826	41·6892
25	34·1578	36·4593	38·9499	41·6459	44·5652
26	36·0117	38·5530	41·3131	44·3117	47·5706
27	37·9120	40·7096	43·7591	47·0842	50·7113
28	39·8598	42·9309	46·2906	49·9676	53·9933
29	41·8563	45·2189	48·9108	52·9663	57·4230
30	43·9027	47·5754	51·6227	56·0849	61·0071
35	54·9282	60·4621	66·6740	73·6522	81·4966
40	67·4026	75·4013	84·5503	95·0255	107·030
45	81·5161	92·7199	105·782	121·029	138·850
50	97·4843	112·797	130·998	152·667	178·503
55	115·551	136·072	160·947	191·159	227·918
60	135·992	163·053	196·517	237·991	289·498
65	159·118	194·333	238·763	294·968	366·238
70	185·284	230·594	288·938	364·290	461·870
75	214·888	272·631	348·530	448·631	581·044
80	248·383	321·363	419·307	551·245	729·558
90	329·154	443·349	603·205	827·903	1145·27
100	432·549	607·288	862·612	1237·62	1790·86

TABLE V.—THE DISCOUNTED PRESENT VALUE OF AN ANNUAL RENTAL OR RETURN (r) of 1, obtainable for n years in all, the rate of Interest being p . $\left[C = \frac{r(1 \cdot 0 p^n - 1)}{1 \cdot 0 p^n \times 0 \cdot 0 p}\right]$.

Years. n .	Rate of interest (p) per cent.				
	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$
1	0·9756	0·9709	0·9662	0·9615	0·9569
2	1·9274	1·9135	1·8997	1·8861	1·8727
3	2·8560	2·8286	2·8016	2·7751	2·7490
4	3·7620	3·7171	3·6731	3·6299	3·5875
5	4·6458	4·5797	4·5151	4·4518	4·3900
6	5·5081	5·4172	5·3286	5·2421	5·1579
7	6·3494	6·2303	6·1145	6·0021	5·8927
8	7·1701	7·0197	6·8740	6·7327	6·5959
9	7·9709	7·7861	7·6077	7·4353	7·2688
10	8·7521	8·5302	8·3166	8·1109	7·9127
11	9·5142	9·2526	9·0016	8·7605	8·5289
12	10·2578	9·9540	9·6633	9·3851	9·1186
13	10·9832	10·6350	10·3027	9·9857	9·6829
14	11·6909	11·2961	10·9205	10·5631	10·2228
15	12·3814	11·9379	11·5174	11·1184	10·7395
16	13·0550	12·5611	12·0941	11·6523	11·2340
17	13·7122	13·1661	12·6513	12·1657	11·7072
18	14·3534	13·7535	13·1897	12·6593	12·1600
19	14·9789	14·3238	13·7098	13·1339	12·5933
20	15·5892	14·8775	14·2124	13·5903	13·0079
21	16·1845	15·4150	14·6980	14·0292	13·4047
22	16·7654	15·9369	15·1671	14·4511	13·7844
23	17·3321	16·4436	15·6204	14·8568	14·1478
24	17·8850	16·9355	16·0584	15·2470	14·4955
25	18·4244	17·4131	16·4815	15·6221	14·8282
26	18·9506	17·8768	16·8904	15·9828	15·1466
27	19·4640	18·3270	17·2854	16·3296	15·4513
28	19·9649	18·7641	17·6670	16·6631	15·7429
29	20·4535	19·1885	18·0358	16·9837	16·0219
30	20·9303	19·6004	18·3920	17·2920	16·2889
35	23·1452	21·4872	20·0007	18·6646	17·4610
40	25·1028	23·1148	21·3551	19·7928	18·4016
45	26·8330	24·5187	22·4955	20·7200	19·1563
50	28·3623	25·7298	23·4556	21·4822	19·7620
55	29·7140	26·7744	24·2641	22·1086	20·2480
60	30·9087	27·6756	24·9447	22·6235	20·6380
65	31·9646	28·4529	25·5178	23·0467	20·9510
70	32·8979	29·1234	26·0004	23·3945	21·2021
75	33·7227	29·7018	26·4067	23·6804	21·4036
80	34·4518	30·2008	26·7488	23·9154	21·5653
90	35·6658	31·0024	27·2793	24·2673	21·7992
100	36·6141	31·5989	27·6554	24·5050	21·9499

PART III.

THE PROTECTION OF WOODLANDS

CHAP.

- I. PROTECTION AGAINST HUMAN ACTS, FARM-STOCK, GAME, RODENTS,
AND BIRDS.
- II. PROTECTION AGAINST INJURIOUS INSECTS.
- III. PROTECTION AGAINST WEEDS, EPIPHYTES, AND FUNGUS DIS-
EASES.
- IV. PROTECTION AGAINST DAMAGE FROM INORGANIC CAUSES.

CHAPTER I.

PROTECTION AGAINST HUMAN ACTS, FARM-STOCK, GAME, RODENTS, AND BIRDS.

Legislative Protection is afforded by *Forest Acts*, and *Rules made thereunder*, in all countries having large forest areas under more or less systematic management. But in Britain there is, as yet, no need for these, and the only legal protection given is that, in 1861, the statutes dealing with damage to woodlands, trees, and shrubs were consolidated in the *Larceny and other similar Offences Act* (sect. 16, referring to "any Forest, Chase, or Purlieu," and sects. 31 to 33, and 35, referring to "trees and woods"), protection being at the same time also given to ornamental trees and shrubs under the *Malicious Injuries to Property Act* (sects. 20 to 22, and 53). Under these it is felony to steal any tree, shrub, or under-wood, 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 is punishable with two years' imprisonment with hard labour.

In Britain woodlands are generally enclosed with walls, fences, or hedgerows, although *boundary marks* are only necessary along march-lines between two different estates under separate ownership. In England an owner or occupier

of land need not put up or maintain any fence between his own and his neighbour's land ; but he must abide by the consequences of not doing so, and must bear the loss caused by cattle straying from a highway ; and he must take care that his cattle do not stray and trespass over the adjoining property. In Scotland a proprietor can force a conterminous proprietor to join him in mutually enclosing their property and to pay the half-share of the expense of making a march-dyke or proper fence, and of keeping it in repair and reconstructing it when no longer repairable.

A proprietor may plant as near to the edge of his land as he likes, but the adjoining proprietor can cut branches overhanging his land.

Commonage and Rights of User are in British woodlands practically confined to the Crown forests, which are not the absolute property of the Crown, but are more or less burdened with rights that are of the nature of real property in so far as concerns the compulsory doing of certain acts, or the not doing of other acts. In England rights of user and of commonage were at one time very extensive, but matters were simplified by legislation about the end of the eighteenth century.

Trespass may disturb game, but does no harm to woodlands. Notices that "*Trespassers will be prosecuted according to law*" are ridiculous, as trespass is not a criminal act, and the only remedy is a civil action claiming damages for such actual damage as can be proved. Any trespasser can be ordered off the property ; and if he refuse to go, just sufficient force may be used as is necessary to eject him.

Fires are almost always caused by *incendiarism, negligence, or sparks from railway engines*. Incendiary fires are usually lighted from malice or to hide other offences. Accidental fires due to imprudence or negligence are chiefly caused by woodmen failing to extinguish fires they have lighted when burning heather or rubbish on cleared areas, or by passers-by throwing away

matches while still burning. The most dangerous months for fire are April, when the dead grass and weeds are dried by the east winds, and August, when the soil-covering is parched by the summer drought; and high wind increases the risk of damage. Fires may seriously damage young plantations and polewoods, and even necessitate the premature felling of older crops, or make them sickly and liable to attacks by insects and fungi. And owing to their resin, Conifers are far more liable to damage than broad-leaved trees. By far the most common form is a *ground-fire* beginning among dry grass or dead leaves, and spreading quickly along the surface of the ground. In young crops the plants are usually killed; in polewoods the bark is often scorched so badly that the poles sicken and die; but in old crops of trees with thick bark the damage is seldom serious, except in Beechwoods. Sometimes, however, if there is much dead herbage or foliage on the ground, the fire becomes so strong as to get hold of the crowns of coniferous poles or trees, and then becomes a *crown-fire* or *conflagration* of the most destructive nature.

With regard to fires caused by sparks or cinders from railway engines, under the *Railway Fires Act*, 1905, which came into force on January 1, 1908, a claim for damage may in each case be made up to £100, but only if written notice of the claim has been sent to the railway company within seven days of the damage occurring, and written particulars of the damage within fourteen days. Light railways and steam-tramways come within scope of the Act. Under sect. 2 a railway company may enter on any land and do all things reasonably necessary for extinguishing or arresting the spread of any such fire, and may, for preventing or diminishing risk of fire in a wood or plantation, enter upon any part of it, or on any adjoining land, and cut down and clear away any undergrowth, and take any other reasonably necessary precautions; but they must not, without consent of the owner, cut down or injure any trees, bushes, or

shrubs. And a railway company exercising such powers must pay full compensation to any person injuriously affected by their exercise, including compensation for loss of amenity.

Fire-Prevention.—All workmen employed in burning heath, turf, or bark should be warned to exercise great caution in using fire, and should be well supervised to see that proper care is taken. Green lanes should be kept free of long dry grass, and woodland paths clear of inflammable matter; and smoking should not be allowed in the woods (especially in April and August).

Where railways run through woodlands, naked strips of ground parallel to them on each side should be planted with wide belts of broad-leaved trees (*e.g.*, Birch or Robinia in Scots Pine tracts), whose foliage would intercept sparks, while below the trees the ground should be swept with stable-brooms or scrub-besoms and kept free of dead foliage, &c., for a breadth of about 20 yards; or the Birch and Robinia should be underplanted with Sweet-Chestnut, or whatever else will grow as underwood, and kept as thick as possible, and such coppice separated from the woods behind by a good broad road kept free of inflammable material. In Conifer woods, where danger from fire is always greatest, the whole area should be divided into compartments by narrow rides kept free of inflammable matter. Such rides will usually stop a ground-fire; and in case of a crown-fire they are convenient bases for beginning operations to check the spread of the fire into other compartments. These rides should run at right angles to the prevailing winds, or generally from N. to S., N.E. to S.W., or N.W. to S.E., and should be planted with a belt or fringe of some broad-leaved tree, Birch being the most suitable tree on poor sandy soil.

Fire-Extinction.—A ground-fire is often easily extinguished, if seen in time; but once it spreads, extinction is more difficult. Hence no time should be lost in trying to put out any fire dis-

covered in or near the woods. On being told that fire has broken out in large woodlands, any forester or woodman should at once collect as many men as possible, with axes, hoes, spades, and besoms, and go to the spot; and mounted messengers should, if possible, be sent to the nearest villages for assistance. On arriving at the fire, the head man should do what he thinks most likely to prevent it spreading. If still only a small ground-fire, it can often be put out by beating the burning line with green boughs cut from trees, or with flat shovels, or by sweeping it back to where it has already passed. If the wind be strong, one must, on account of the smoke and heat, begin at the flanks of the line of fire and work along these towards the centre; but when the air is still, or there is merely a slight breeze, work may be begun simultaneously at different points along the running edge of flame.

If a strong breeze has enabled the fire to make considerable headway, it is best to go ahead of the line of flame for some distance and clear all inflammable material from a strip several yards wide, in order to check its progress, although this entails sacrificing part of the crop to save the rest. This measure is all the more effective if a counter-fire can be started along the inside of the cleared line, so as to eat its way along the ground and meet the approaching fire, thus decreasing the danger of sparks being carried across the cleared line. Compartment boundaries, cart-tracks, and old paths form good base-lines, easily found and cleared; and while this is being done, the work of extinguishing along the edges of the line of fire should also be vigorously carried on.

If the ground-fire be likely to send sparks over the cleared line, counter-firing is necessary—*i.e.*, setting fire to the inner edge of the cleared line, and burning against wind, to meet the advancing fire. This new line of fire should be cautiously guarded to prevent it burning down wind and starting a new fire. When once well started such a line of counter-fire eats its

way forwards, as the heated air from the main line of fire tends to attract the new line towards it.

Wide belts planted with broad-leaved trees are the best means of checking crown-fires, and should always be provided in extensive Conifer woods exposed to risk from fire. The path or line used as a base can be broadened, if necessary, by rapidly clearing away the trees along the outside edge. But the success of this and of clearance of the ground to work against a ground-fire depends on starting far enough ahead to complete operations before the fire can reach the newly cleared line. Poles and trees felled should be lopped, and the branches removed to the far side of the woods, to obviate risk of their catching fire from sparks.

Fires inside of hollow stems may be put out by filling the hollow with sods of turf and earth; or if this cannot be done, the tree should be felled and the fire put out with earth.

When a fire has been put out, watchmen should be left, especially when there is any strong breeze, to see that it does not break out again; and in August watch should be kept all night long, and earth should be thrown on all smouldering stems glowing in the dark.

Remedying Fire-Damage.—Badly damaged young Conifer plantations usually need to be cleared and replanted; but young broad-leaved trees often reproduce themselves well if coppiced. Owing to its smooth thin bark, Beech is the least hardy against fire; even a slight ground-fire injures it. The crops least liable to damage are old woods, especially of thick-barked Oak or Pine. When the foliage in old woods looks unhealthy after a ground-fire, or trees die off here and there, it is often necessary to clear the crop, especially in conifer woods, where the forester and his woodmen should pay special attention to injurious insects, and in particular to kinds which breed in the roots and the lower parts of the stems of poles and trees.

Farm - Stock cause damage by nibbling buds, leaves, and shoots ; gnawing and stripping bark ; injuring roots with their hard hoofs and horny feet ; bending back young growth and saplings ; dislodging soil on slopes ; stamping down damp, heavy clay soil, and loosening light sandy soil ; and breaking down the sides of drains. **Horses** usually prefer the short grass along roadsides to the ranker grass growing inside the woods ; but they are fond of young foliage and shoots, which they can strip to a considerable height, and young horses are fond of gnawing the bark. Their great weight and their iron shoes cause a good deal of damage to young seedlings, and to superficial roots. **Sheep**, besides feeding on grass, are fond of nibbling young leaves and shoots, and often do considerable damage when frequently grazed in any one wood, their tread tending to break up loose sandy soil only thinly overgrown with grass or weeds. But **Cattle** only browse on leaves and twigs when grass and other herbage are scanty ; and then they bend down strong saplings under their chests to reach the foliage, loosen and dislodge soil on hill-slopes, and damage young growth with their hard horny feet. But the grazing of cattle may be of use where there is a strong growth of grass in young pole-woods. Young cattle, horses, or sheep do more damage than old beasts. Even where grass and herbage are plentiful, they nibble young timber-crops from wantonness and when changing their teeth. If cattle in thin condition are grazed in woods after being poorly fed in winter, they do much damage to the young plantations, as they greedily devour all they can.

The extent of damage varies mainly according to the kind of animal grazed, but also depends on the nature and age of the timber-crop, the soil and situation, the number of the animals grazed, and the time and manner of their being herded in the woods. Different kinds of trees suffer to a different extent, as grazing animals usually prefer the foliage of broad-leaved trees to that of Conifers, and only browse on the latter in the absence

of the former. But the damage done to Conifers is generally more serious, because they have not such recuperative power in repairing damage. If badly bitten, Scots Pine usually remains more or less stunted, while Silver Fir soon recovers. The shallow roots of Spruce are more damaged by hoofs than deep-rooting Pine and Larch. In all Conifers, however, injuries to bark or shoots enable parasitic fungi to effect an entrance. Grazing animals prefer the leaves and shoots of hardwoods to those of softwoods, but seldom touch Lime, Birch, or Alder. Among Conifers they prefer the shoots of Firs to those of Pines. Horses and sheep usually prefer young Oak foliage, though sheep graze readily on Pine and Birch as a change of diet on poor heathery tracts. The younger the crop, the greater is generally the damage. When there is rank growth of grass, damage by cattle and sheep is usually very slight, and grazing may do good in checking the growth of grass and treading it down.

In Britain, protection against farm-stock, as also against deer and ground-game, is by **Fencing**, the cheapest and best form of fence now being wires strained on wooden posts. The *wires* are strained on *posts* (7 to 7½ ft. × 6 to 8 in.) about 80 to 100 yards apart or more, and supported by staples driven into *stobs* or smaller intermediate posts (5 to 6 ft. × 3 to 4 in.) at 9 to 12 ft. apart, and further kept in position by staples fixed in two or three *droppers* or short upright pieces of wood put at 3 or 4 ft. apart between the stobs. The straining-posts of Oak, Larch, or creosoted timber are set about 3 to 3½ ft. in the ground, and project about 3 ft. 9 in. to 4 ft. above it; and at angles where a very great strain has to be borne, additional strength is given by fitting the foot of the posts into a sole and supporting it with a strut (Fig 32). Pits have to be dug for the posts, either with a pick on hard ground or with post-hole boring implements on soft ground; but the stobs, sharp-pointed

at lower end, are usually malleted in to about one-third of their length, so as to stand at the height needed. All the stobs between two straining-posts having been put in proper position in a straight line, the wires are strained and stapled on the stobs at their proper distances apart; then the droppers are also fixed with staples to help to keep the wires in place.

A post-and-wire fence to resist horses, cattle, and sheep should be about 3 ft. 9 in. to 4 ft. high, and should have six strands of wire; and it is more effective if the top strand consist of barb-wire. Such a fence (with well creosoted posts) lasts for about twenty years, and costs little to maintain. If the fence is only against sheep, a 3 to 3½ ft. fence, with four to five wires, is sufficient; and it is more effective if the third and the top wires are barbed.

A good creosoted fence of the above description, 3 ft. 9 in. to 4 ft. high, with six wires (five smooth, and top barbed), usually costs 10d. to 1s. per running yard; while a lighter fence against sheep only can be put up for 6d. to 8d. But the cost varies with the height of the fence, and the size and number of wires used; and the larger the area, the smaller is the cost per acre for fencing. If plantations were made in squares, the cost would only increase twofold while the enclosed area extended fourfold; so that, if only light fencing were

Fig. 32.

needed at an average cost of 6d. a running yard, the cost per acre would vary as follows:—

Area in acres .	1	4	16	64	256	1024	4096
Yards of fence	280	560	1120	2240	4480	8960	17,920
Total cost . .	£7	£14	£28	£56	£112	£224	£448
Cost per acre .	140s.	70s.	35s.	17s. 6d.	8s. 9d.	4s. 4½d.	2s. 2¼d.

As plantations are seldom made with straight-line boundaries, the acreage enclosed gives no idea of the number of yards of fencing needed, which can only be known by measuring on a map, or on the ground. The difference in cost is often great, as 1 square mile of plantation (640) acres *in a square* needs 4 miles or 7040 yards of fencing, and at 6d. a-yard costs £176, or 5s. 6d. an acre; while the same area *as a rectangle twice as long as it is broad*, needs 5 miles or 8800 yards of fencing, amounting to £220, or 6s. 10½d. per acre; but if *thrice as long as broad*, it needs 6⅔ miles or 11,733 yards of fencing, costing £293, or 9s. 1⅞d. per acre. It is therefore economical to make plantations as large and square or compact as possible.

The cheapest form of fence against Highland cattle and sheep known to me is one erected in 1908, in the Lorne district of Argyllshire, with uncreosoted Larch thinnings, and intended to last for about twelve years. Formed of five strands of No. 8 galvanised wire (with 5½, 5½, 6½, and 7½ in. between the wires), and a top-strand of 4-barbed wire (8½ in. above), it stands 39 in. high, has a total length of 2850 yards, encloses 97½ acres, and cost in all £53, 7s. 2d., or 4½d. per running yard, and 11s. per acre enclosed. The straining-posts and stobs were of young undressed and uncreosoted Larch thinnings, and the droppers (2 × 1 in.) were cut from Larch slabs. No special outlay was incurred for carting, done at odd times when the cart and horse were not otherwise employed. The details of cost were as follows:—

1. *Timber*—

36 straining-posts (7 ft. $\times$ 6½ in.), at 80 yards apart on average, at 2s. each .	£3 12 0
36 stobs used as stays, &c., at 3½d. each .	0 10 6
439 stobs (5 ft. $\times$ 3½ in.), at 18 ft. apart, at 3½d. each	6 8 0
475 long droppers, 40 $\times$ 2 $\times$ 1½ in., at 9 ft. between stobs; 1900 short droppers, 23 $\times$ 2 $\times$ 1½ in., at 3 ft. apart; 2375 droppers=109 cubic ft. of 2 $\times$ 1½ in., at 1s. per cubic ft. (=over ½d. each)	5 9 0
	<hr/> £15 19 6

2. *Wire*—19 cwt. No. 8 galvanised wire, 7 cwt. 4-barbed wire, and 3 cwt. galvanised staples 17 10 4

3. *Labour in Construction*—

1 man for 12 weeks, at 22s.	£13 4 0
1 man for 5 weeks and 2½ days, at 20s.	5 8 4
	<hr/> 18 12 4

4. *Carriage of Material*; estimated, but not paid for 1 5 0

Total £53 7 2

Fig. 33 gives some idea of this cheap fence.

Damage by Game (Fig. 34) often causes great loss in woodlands, because in most parts of Britain more attention is paid to game-preservation than to growing timber for profit; and game-preservation means disturbing the balance of nature, and thus (by destroying their enemies) favouring many kinds of animals that damage young plantations and polewoods. Yet in some parts of the country shooting rents are often higher than the ordinary profit hitherto derived from woodlands. But if

rabbits were kept down plantations would cost less, and be much more profitable than at present.

As regards the damage done, game may be classed as (1) *big*

Fig. 34.

Damage caused by Game and Rodents.

a. Hornbeam gnawed by *Field-mice*.
b. Beech frayed by *Deer*.

c. Ash and Beech gnawed by *Rabbits*.
d. Spruce gnawed by *Squirrels*.

game, including red, fallow, and roe-deer; (2) *ground game*, hares and rabbits; and (3) *feathered game*.

Red Deer (*Cervus elaphus*) eat acorns and beech-nuts, bite off buds and young shoots, gnaw the bark of poles in

winter, and strip the bark in spring and summer, and use saplings or poles as "fraying-stocks," when rubbing the velvet from their antlers in July and August, or when rutting in September and October. The nibbling of buds and shoots kills young plants at once, and when often repeated cripples and stunts older plants. Oak, Ash, Maple, Sycamore, and Beech are the trees deer prefer to gnaw, while young softwoods are naturally preferred as fraying-stocks. The gnawing takes place horizontally, the deer turning their heads sideways and nibbling the whole of one side of the bark on poles up to a good size, so long as the rind is soft and sappy. In winter they both gnaw and peel the bark at about the height of their head, or higher if much snow is on the ground, and the gnawed stems show horizontal teeth-marks with narrow lines of bark and cambium between. But far more injurious is bark-stripping (of Spruce chiefly) in spring and summer while the sap is in flow. The bark is usually bitten through low down, and the deer moves back, holding on firmly with its teeth, until a strip from 2 or 3 to 6 ft. long tears off. Sometimes the lower end bitten through is 4 to 6 in. broad, but the strip gradually becomes narrower till it comes away from the stem, often high up, and is eaten. Spruce-woods from 20 to 40 years old are specially liable to injury, then 15- to 20-year-old Beech, Silver Fir, and Oak so long as the bark is smooth. Larch, Ash, Elm, Maple, and Sycamore are less liable to attack, and Scots Pine, Birch, and Alder least of all. Among Conifers, Silver Fir recovers best, while Scots Pine usually remains stunted after being nibbled. Young poles with smooth rind are always attacked first, and peeling stops when thick rough bark is formed. The danger is greatest after the first thinning of a plantation, and clean, well-grown poles are more likely to be damaged than those still rough with twigs. Damaged poles often rot far up into the stem, and break from wind or snow; or the lower end of the stem is useless for timber up to 15 or 20 ft. high. As

British deer-forests are mostly heathery wastes, the damage done is seldom extensive; but where woods are open to the deer the trees can easily be very badly injured (*e.g.*, as at Invercauld). *Prevention of damage* can only be ensured by enclosure and fencing to a height of at least $5\frac{1}{2}$ ft.

Fallow-Deer (*Dama vulgaris*) eat acorns and beech-nuts, nibble buds and shoots, and use young poles as fraying-stocks in August and September, but rarely strip the bark even in deer-parks, and not at all in open woods.

Roe-Deer (*Cervus capreolus*) can do a great deal of damage in young woods and nurseries, and in some parts of Scotland (especially in the Highlands) are almost as destructive as rabbits, through biting off the buds and shoots of young trees during the winter and the early spring, and using young saplings as fraying-stocks from April to June, and in their rutting time in July and August. Both for browsing and for fraying they prefer the more valuable trees interspersed throughout plantations, such as Larch, Silver Fir, Acacia, Oak, and Ash, and other soft-barked kinds. Where only a comparatively small number of such young trees have to be protected, this can be done by smearing in late autumn the buds of their leading-shoots with some ill-smelling substance (the use of tar being avoided, as it prevents the buds from opening in spring), or by tying small square pieces of newspaper round the cluster of top buds of Conifers, or by fixing a small, thin, and very cheap tin crown with sharp points specially made for this purpose, and so soft as not to hinder the sprouting of the buds in spring. Otherwise young plantations and nurseries have to be protected by wire-fencing about 5 to $5\frac{1}{2}$ ft. high. Seed-beds and nursery-lines can be protected by laying poles over them, or hanging feathers, pieces of broken looking-glass hung on strings, &c.; but a high fence is by far the best protection.

Ground Game.—Both hares and rabbits are very destructive in nurseries and young plantations by biting through young

shoots and gnawing the bark of poles and trees. But they are seldom found together, as hares shun rabbit-infested places. And being far fewer in number than the prolific burrowing rabbit, hares are more easily kept down, though individually the hare, being larger, does more damage than a rabbit, and often apparently bites off leading-shoots in young plantations from mere wantonness, leaving them lying on the ground.

It is easy to distinguish between the teeth-marks of hares and rabbits, the marks left by hares being longer, broader, and fewer than those of rabbits, which are shorter, narrower, and usually in two to six more or less parallel grooves, but are larger, broader, and less numerous than the finely-chiselled teeth-marks of mice and moles. **Hares** (*Lepus timidus*) chiefly gnaw Ash, Maple, and Sycamore, Beech, Elm, Hazel, and Robinia (also orchard-trees), but the damage is less concentrated than that of rabbits. In the Scottish Highlands the blue hare (*L. variabilis*) may during winter commit serious damage in young plantations not protected by wire-netting. **Rabbits** (*Lepus cuniculus*) often ruin Hazel- and Ash-coppice near where they burrow, sometimes making an almost entire clearance while snow lies on the ground. They do great damage in young plantations up to seven years of age; and in most places it is mere waste of time, land, and money to try and grow young timber-crops without careful and expensive wire-netting of each plantation. But wire-netting is worse than useless unless the area enclosed is absolutely cleared of rabbits, and netting of 1-inch mesh is used to keep out very young rabbits. If once these get inside an enclosed plantation, it becomes a warren, and they very soon do great damage. The only kinds of trees they do not attack are old thick-barked Oak and Corsican Pine, the latter being usually damaged to a far less extent than Larch, Douglas Fir, Spruce, or Scots Pine.

Protection against ground-game can only be secured by wire-netting nurseries and young plantations. Broad-leaved saplings

gnawed can be cut back to the stool; but young Conifers are usually damaged beyond recovery. Young park-trees, and exotics scattered experimentally in the woods, can be protected by binding thorns or rough brushwood round the stems. Rabbits may be trapped, ferreted, or shot, but it is often difficult to exterminate them. Smearing the shoots with ill-smelling substances cannot be relied upon to protect young plants. Wherever there are even only a few rabbits, young plantations need to be protected for at least seven years by being carefully fenced with 1-inch-mesh wire-netting, which adds considerably to the initial cost, though this extra charge should really be debitable to the game account. Wire-netted plantations should be carefully examined from time to time to see that no rabbits have got in; because, if once inside, unless they are all killed the plantation becomes a warren, and the rabbits may do serious damage. To be rabbit-proof, wire-fencing must now have a 1-inch mesh for the first 18 inches (besides 6 inches being bent outwards underground), and a $1\frac{1}{4}$ -inch or $1\frac{1}{2}$ -inch mesh for 2 ft. above that; and, in addition to being bent outwards underground for 6 inches at lower end, it must either be bent outwards at the top, or else the posts should lean slightly outwards to prevent climbing. If set upright, and the wire be not bent outwards, rabbits can jump up, climb over, and get into the plantation, as they have now in many localities developed climbing-power since close-meshed wire-fencing was introduced. The *additional cost* of providing and fixing strong small-mesh rabbit-proof wire-netting of 4 ft. breadth, bending it outwards underground for 6 in. at lower side to prevent burrowing, and making it also bend over somewhat at the top to prevent rabbits climbing over, comes to about 6d. to 7d. a running yard, which brings up the total cost to about 1s. 6d. a-yard for *cattle-and-rabbit* fencing, and 1s. $1\frac{1}{2}$ d. to 1s. 3d. a-yard for *sheep-and-rabbit* fencing.

Squirrels (*Sciurus vulgaris*) may also do serious damage

(Fig. 34), especially in Conifer woods. They feed on most kinds of tree-seeds, but chiefly on acorns, and beech and hazel nuts; they eat the flowering buds of Oak, Beech, Maple, Sycamore, and Conifers in late winter; and in summer and autumn pick cones to pieces, even before ripe, to suck the juice and eat the seeds. Hence seed-production is poor wherever squirrels are numerous. But the greatest damage they do is when, during spring and summer, they seat themselves on the branch-whorls of Conifer poles or trees and gnaw the soft bark, often completely girdling the top, which then dries, rots, and ultimately falls off. In the North of Scotland so much damage of this sort has been done, especially in Scots Pine and Larch woods, that the landowners in Ross, Cromarty, and neighbourhood had to form squirrel clubs for shooting and trying to exterminate this pretty but excessively destructive pest; and over 15,000 were shot within five or six years. They are very destructive in some parts of Ireland, where they are said to have been introduced about fifty years ago by two boys letting loose a pair given to them as pets. Trapping is less effective than shooting during the nesting time in May, when a charge of small shot will kill both mother and brood. Where squirrel raids are not permitted during the nesting season, the best time for shooting them is in February, before the game birds begin to lay.

Mice and Voles do damage by eating seed and gnawing plants in nurseries and plantations (Fig. 34). Their attacks are often hard to combat, and sometimes this can only be effected when nature restores the proper balance by increase of natural enemies, or by epidemic disease. Mice and voles are always found in woods adjoining fields. The wood-mouse lives in the woods, but the voles infest the fields in summer, and live in the woodlands in winter. Both are very prolific, and increase enormously during a mild winter followed by a dry spring and summer. But hard frost without snow, heavy rain followed by frost, and cold damp weather often kill them off in a short time.

They abound most in young plantations with a strong growth of grass, giving them shelter and food. They devour acorns, beech-mast, and hazel-nuts, Chestnuts, Lime and Hornbeam seed, but care little for the seed of other broad-leaved trees or Conifers. They gnaw the young bark of Beech, Oak, Ash, Hornbeam, Larch, and most other trees; but the various kinds of mice and voles differ in this matter, some beginning to gnaw close to the ground, others only a little way up, and others only after climbing a good height up the tree. In nurseries, whole rows of one- and two-year-old Spruce are sometimes eaten through in seed-beds; and in plantations plants may either be bitten through, or gnawed partly or entirely round the stem, according to age and size, young Beech and Larch of an inch and more in diameter often being cut right through. As the young trees grow and the bark thickens, there is less danger of their being gnawed.

The Mouse genus (*Mus*) has a pointed muzzle, large ears, and a naked tail as long as its body. *The Wood-mouse or long-tailed Field-mouse* (*M. sylvaticus*) mostly devours seeds, and only occasionally gnaws the bark. *The Vole* (*Arvicola*) has a broad head with small ears hidden in fur, short legs, and a short hairy tail. Several species do damage in woodlands. *The Field-vole or true Field-mouse* (*A. arvalis*), which migrates from the fields to the woods in autumn, devours seed and gnaws the bark of saplings and poles near the ground. It is not a good climber. *The Common Field-vole* (*A. agrestis*) does similar damage, but often higher up, as it is a better climber. *The Red or Bank-vole* (*A. glareolus*), which does damage chiefly by gnawing, often climbs up 10 or 12 ft. to reach the soft bark. *The Water-rat* (*A. amphibius*), the largest vole, always lives below ground and gnaws roots, but never occurs in large numbers.

The best preventive and exterminative measure against mice and voles is to protect their natural enemies (owls, buzzards, crows, ravens, sea-gulls, kestrels, rooks, hedgehogs, weasels, stoats, porcupines, martens, badgers, and foxes), so far as sport permits of this; but cats are of little use. Nurseries are best formed away from where fields march with woods. But when once the balance of nature has been disturbed by measures for

game-preservation, mice and voles rapidly increase in enormous numbers, especially in dry mild seasons, and may inflict serious damage on plantations. When small plantations are attacked a surrounding trench about 18 inches deep can be dug, wider below than above, into which the voles fall and cannot climb out again. But during plagues (as in 1864-67 and 1891-92), large numbers can be killed by laying oatmeal poisoned with barium carbonate or phosphorus paste in drain-tiles throughout the plantations, although the attacks generally continue till the balance of nature is restored by increase of the birds and other animals which prey on mice and voles.

Birds are on the whole far more beneficial in preying on mice, voles, and insects, and on snails and slugs in nurseries, than injurious in eating seed and damaging plants, although in nurseries the seed-beds may often need protection by moistening the seed and rolling it in red-lead powder, or by covering the seed-beds with a wire-net framework. As regards their general importance to the forester, birds may be classified as follows:—

I. Decidedly useful.		II. Rather useful.		III. Rather injurious.	IV. Decidedly injurious.
<i>Cuckoo.</i> <i>Roller.</i> <i>Hoopoe.</i> <i>Starling.</i> <i>Tits.</i> <i>Creepers.</i> <i>Swallows, Martins, and Swifts.</i> <i>Warblers.</i> <i>Nightingales.</i> <i>Wrens.</i> <i>Accentor (Hedge-Sparrow).</i> <i>Redstarts.</i>	<i>Robin.</i> <i>Whitethroat.</i> <i>Stonechat.</i> <i>Oriole.</i> <i>Wagtails.</i> <i>Titlark.</i> <i>Owls *</i> (except <i>B. max.</i>). <i>Flycatchers.</i> <i>Nuthatch.</i> <i>Black-headed Gull.</i>	<i>Bullfinch.</i> <i>Goldfinch.</i> <i>Linnet.</i> <i>Greenfinch.</i> <i>Siskin.</i> <i>Larks.</i> <i>Woodpeckers.</i> <i>Thrushes.</i> <i>Blackbirds.</i> <i>Jackdaw.*</i> <i>Rook.*</i>	<i>Common Crow.*</i> <i>Hooded Crow.*</i> <i>Cornish Chough.</i> <i>Buzzard.*</i> <i>Kestrel.*</i> <i>Lapwing.</i> <i>Plover.</i> <i>Snipe.†</i> <i>Honey Buzzard.</i> <i>Woodcock.†</i>	<i>Shrikes.</i> <i>Magpie.</i> <i>Raven.</i> <i>Eagle Owl (B. max.).</i> <i>Sparrow-hawk.</i> <i>Goshawk.</i> <i>Merlin.</i> <i>Red Grouse†</i> (occasionally).	<i>Capercaillie.†</i> <i>Blackcock.†</i> <i>Pigeons.</i> <i>Doves.</i> <i>Jay.</i> <i>Nut-cracker Crow.</i> <i>Chaffinch.</i> <i>Mountain Finch.</i> <i>Hawfinch.</i> <i>Crossbills.</i>

Italics.—Birds benefited by a close time (from 2nd March to 31st July) under the Wild Birds' Protection Acts.

* Those also keep down mice and voles, as well as insects.

† Protected under the Game Laws; Grouse, Capercaillie, and Blackcock have also a close time, but not Snipe or Woodcock.

Among the *decidedly useful* class, the Owls for mice and voles, the Cuckoo for hairy caterpillars, and the Starling and the Hedge-Sparrow for other insects generally, are the forester's best friends. The Cuckoo usually lays its eggs in the nests of Starlings or Hedge-Sparrows ; but to protect the Starling's eggs and young against Cuckoos, wild cats, and other enemies, nesting-boxes, which cost little and last many years, can be hung up in the branches of trees.

The *rather useful* class includes birds subsisting chiefly on grain, but also preying to some extent on insects ; while the *rather injurious* class do more harm by destroying eggs and killing small birds, than good by feeding partly on insects, mice, and voles.

The *decidedly injurious* class includes game-birds of the Grouse family, Pigeons, Jays, and Finches.

Destructive birds of the Grouse family (*Tetraonidæ*) are the Capercaillie or Cock-of-the-wood (*Tetrao urogallus*) and the Blackcock (*T. tetrix*), and also, but very rarely, the common Red Grouse (*Lagopus scoticus*).

The *Capercaillie* is only found occasionally among Conifers in mountain tracts. During the winter and the spring it lives near nurseries or young plantations, and feeds on the buds and foliage of young shoots ; and as the birds keep very much to one feeding-ground, their destructiveness is more apparent than if spread over a larger area. When snow covers the ground, and only the tips of leading-shoots appear above it, they bite them off. Spruce and Silver Fir are more attacked than Scots Pine. But its spring diet includes insects.

The *Blackcock* of heathery moors and hill-slopes feeds mostly on the buds of Birch, Alder, Saugh, and Rowan, and on Rowan-berries. But when these are destroyed by exceptionally severe frosts (as in November 1909) or become exhausted, the birds attack plantations or nurseries near their haunts. They feed mostly on the ground ; and when forced to feed on buds, they attack Larch, Spruce, Silver Fir, and Pines almost indiscriminately, wherever within easy reach. They are fond of the male catkins of Birch, Alder, and Hazel in the early spring. The common *Grouse* has recently done much damage by picking the buds from young Larch plantations near Loch Lomond (Buchanan Castle estate), and has also been seen feeding on Larch in Perthshire (Taymouth estate).

The Pigeons (*Columbidæ*) include the Wood-pigeon, Cushat or Ring-dove (*Columba palumbus*), the Wood-dove or Stock-dove (*C. ænas*), and the Turtle-dove (*Turtur auritus*). The two former remain all the year in England, but the last-named is merely a summer visitor from May to September.

The Wood-pigeon is chiefly found in Conifer woods, where it consumes a large quantity of ripe seed, buds, and catkins of different trees at flowering-time. Where numerous, they often break the brittle leading-shoots of Douglas Fir, Silver Fir, and Spruce, by settling on them. The Stock-dove mostly frequents mixed broad-leaved woods, and feeds on buds, flowers, and fruits. The Turtle-dove is usually found in small woods among fields and meadows, and feeds principally among the latter. During the spring-time all three species assemble in flocks, and do great damage to sowings in fields and nurseries; and in autumn, when acorns and beech-nuts are ripe, the two larger kinds feed on the mast, but without doing much damage. Coating the seed with red-lead powder is the best protection in nurseries.

Among Jays, the Common Jay (*Garrulus glandarius*) and the Nutcracker (*Nucifraga caryocatactes*) are mainly destructive.

Although they scratch up acorns and beech-nuts, and devour the cotyledons of young seedlings, the chief damage they do is in destroying the eggs and young of insectivorous singing-birds. Seed-beds can be protected with a framework, but shooting is better.

Though some kinds of Finches (*Fringillidæ*) are more beneficial than harmful, others do much damage. The more injurious kinds are the Chaffinch or Pie-finch (*Fringilla cœlebs*), the Brambling or Mountain Finch (*F. montifringilla*), and the Hawfinch (*Coccothraustes vulgaris*); while the Common Crossbill (*Loxia curvirostra*), the only *Loxia* common in Britain, must also be classed along with them.

The Chaffinch and the Mountain Finch collect in large flights in autumn near nurseries, and in spring they feed on the cotyledons of the young seedlings. The Hawfinch is a more varied feeder, and does more damage in gardens and orchards than in nurseries or woods. Where Finches are troublesome, seed-beds may need the protection of a framework. Other-

wise coating the seeds with red-lead is cheap and effective. Tying threads or twine across the beds, with white feathers, &c., knotted into them, is also serviceable, but scarecrows are merely of temporary use. The Crossbill feeds mostly on tree-seeds and berries. After biting off Spruce or Pine cones, it uses its mandibles to displace the bracts and lay bare the seed, or else it splits open the scales of the cone from above downwards until it gets the seed lying at the base. The damage done is often great, as the birds frequently come in large flocks. Sometimes it also (like Blackcock) picks the buds from young Scots Pine plants.

CHAPTER II.

PROTECTION AGAINST INJURIOUS INSECTS.

Life-History of Insects.—Insects belong to the *Hexapoda* ("six-footed") class of animals having jointed feet (*Arthropoda*). Their bodies consist of three main sections—(1) *head*, containing organs of sense ; (2) *thorax*, to which six legs (three pairs), and generally also two pairs or one pair of wings, are attached ; and (3) *abdomen*, containing organs of reproduction ; and they pass through one or more of various stages of development (*Metamorphoses*), each distinguishable from the preceding and the succeeding stages, namely—(1) *Ovum* or egg, (2) *Larva* or grub, (3) *Pupa* or chrysalis, and (4) *Imago* or mature adult insect. When all these four stages are well defined, an insect is said to have a *complete metamorphosis* ; but with many insects there is merely an *incomplete metamorphosis* with no distinct pupal stage, because the larva gradually becomes transformed into the imago, the pseudo-pupa being then known as a *nymph*, and the transformation of a *nymph-pupa* into the perfect insect taking place by the already formed wings being liberated at the last moult or change of skin ; while some wingless primitive insects (*Aptera*) undergo *no metamorphosis* at all. The *Ova* or eggs vary greatly in size, shape, and colour. Eggs are laid singly or in clusters on different parts of trees, and sometimes lie naked and unprotected, or are protected within the bark or by some special covering. The *Larva* usually hatches out in the course of a few weeks, but often hibernates within the shell, and only emerges in the following spring. The larvæ of most beetles are called *grubs* ; the 16-footed larvæ of butterflies and moths (those of spanners have only 10, and a few mining-moths have none) are called *caterpillars* ; the 18- to 22-footed larvæ of sawflies have tail-like extremities and are called *tailed-caterpillars* ; while the larvæ of flies, which have neither feet nor any complex structure of the head, are called *maggots*. The larvæ of many beetles have 3 pairs of legs on the first three (thoracic) segments after the head ; the caterpillars of moths and butterflies have these also, and in addition

from 2 to 5 pairs of *prolegs* or clasping feet attached to the abdominal segments, the last pair of which (*claspers* or *anal prolegs*) are on the terminal segment. As it gradually grows in size, the larva moults its skin several times before pupation. The pupa sometimes lies unprotected on the ground under moss and dead foliage, or in fissures or under bark-scales, and at other times it is enclosed within a woven *cocoon* (often of large size for some spinning-moths), while with flies the last larval skin forms a protective covering. The longest stage of development is that in which the insect hibernates; and this is very often the larval stage, although many beetles hibernate as adults. The egg and the pupal stages usually last only from two to four weeks, except with insects which hibernate thus.

As soon as the adults appear, they usually pair at once and reproduce themselves, the male generally dying soon after pairing,—except in the case of beetles, which often hibernate, and of bees which live for four or five years.

The *Generation* of any insect, or the complete cycle from egg to egg, varies greatly, being *multiple* in plant-lice and ichneumon-flies, which produce several generations in a year; *double* in some bark-beetles and sawflies, which produce two generations in each year; *single, simple, or annual* with most butterflies and moths, which yearly produce one generation; *biennial or two-yearly* in wood-wasps, the Pine resin-gall tortrix, and many longicorn beetles; and *plurennial* in the cockchafer, which takes at least three and usually four years to complete its generation. Occasionally there are two generations in three years (as in *Bostrichus bidens*), but this is unusual.

Insects with complete metamorphosis feed only as larvæ and adults, though only in exceptional cases (*e.g.*, Pine-weevil) doing damage as adults; but among insects with incomplete metamorphosis the nymph also feeds. In both groups the larvæ are often very destructive.

Any attempt to group injurious insects either with regard to the trees they attack or to the age of the crops generally attacked (seedlings and young plants, thickets, pole-woods, and highwoods) is unsatisfactory, as many insects are dangerous at all stages of tree-growth, and feed more or less indiscriminately on different kinds of trees when once they increase in unusual numbers. But it may be remarked that most weevils, some leaf-rollers, and cockchafer-grubs usually attack seedling growth and young thickets, and that pole-woods and older crops are mostly attacked by moths, and then by bark- and cambial-beetles when the trees grow sickly. The caterpillars of the Pine owlet-moth and the Pine spanworm always attack pole-woods before migrating to older crops on their numbers increasing largely. With regard to the parts of the tree chiefly

attacked, one can distinguish between **Root-destroyers**, such as the mole-cricket and the cockchafer grub ; **Wood-borers**, comprising the larvæ of wood-wasps, cervicorn beetles, some bark-beetles, and goat-moth caterpillars ; **Bark-beetles**, and some weevils, which often, both as beetle and larva, either destroy the cambium and the sapwood, or else hollow out the pith in young shoots (*e.g.*, some *Hylesinini* and *Tortricide*) ; **Bud- and Leaf-destroyers**, including other weevils, most moth- and sawfly-caterpillars, leaf-beetles, cockchafers, and some plant-lice (*e.g.*, Larch aptera) ; **Producers of Deformities and Malformations** on foliage, shoots, and fruits, as gall-wasps, gall-midges, and plant-lice (*e.g.*, Spruce aphid).

But the now generally accepted scientific classification into orders is as follows:—

A. *With complete metamorphosis* (egg, larva, pupa, adult).

- I. **Coleoptera** ("shield-wings") or **Beetles**, having 2 pairs of wings, the front pair being hard and horny (*elytra*), and forming shields for protecting the soft membranous hind-pair used in flying ; mouth for biting.
- II. **Lepidoptera** ("scale-wings") or **Butterflies and Moths**,¹ having 2 pairs of flat membranous wings more or less completely covered with flat scales ; mouth biting for larva, and sucking for adult.
- III. **Hymenoptera** ("skin-wings") or **Sawflies, Wasps, Bees, and Ants**, having 2 pairs of wings, all membranous, with few wing-cells, and a distinct dark area along the upper border ; mouth for biting, or for both sucking and biting.
- IV. **Diptera** ("two-wings") or **Flies**, having only 1 pair of membranous wings attached to mesothorax, the hind pair being only rudimentary and aborted into two small stalked knobs (*halteres*) used as poisers or balancers ; mouth biting for larva, and sucking or piercing for adult.

¹ *Butterflies* have feelers always ending in a club-like knob, are mostly diurnal in habit, and are of little or no importance to the forester ; whereas *moths* with feelers variable in form, but never ending in a knob, are usually more or less nocturnal in habit, and are often very destructive.

B. *With incomplete metamorphosis.*

V. **Hemiptera** ("half-wings") or **Bugs, Plant-lice, and Scale-insects, &c.**, having 2 pairs of wings, either all membranous (sub-order **Homoptera**, with fore and hind wings *similar*, or **Plant-lice and Scale-insects, &c.**) or else the front pair leathery at base and opaque (sub-order **Heteroptera**, with fore and hind wings *different*, or **Bugs**); mouth formed into a snout (*proboscis*) for sucking and piercing.

VI. **Orthoptera** ("straight-wings") or **Grasshoppers and Crickets**, having 2 pairs of wings, the front pair narrow, leathery, and with straight veins, the hind pair fan-shaped; mouth for biting.

VII. **Neuroptera** ("nerve-wings") or **Dragon-Flies and Lace-wing Flies**, having 2 pairs of wings with a network of veins; mouth for biting.

VIII. **Thysanoptera** ("fringe-wings") or **Thrips**, small insects having 2 pairs of very narrow wings fringed all round with fine hairs; mouth for biting, but weak.

C. *Without metamorphosis.*

IX. **Aptera** ("without wings") or **Springtails, &c.**, small insects having no wings, but either a locomotive apparatus like a spring beneath, or a process like a tail; mouth for biting, but weak.

In our woodlands **beetles** and **moths** are by far the most destructive insects, then **sawflies** and **plant-lice**. In beetles the structure and the different segments of the adult are distinguishable in the pupa, but in moths they are still indistinguishable. No insects of the orders *Orthoptera*, *Neuroptera*, *Thysanoptera*, or *Aptera* damage trees, while many of the *Neuroptera* are useful by preying on the injurious kinds of insects.

Damage by Insects.—Conifers, and especially Pine, Larch, and Spruce, are usually much more attacked than broad-leaved trees; and the attacks are generally far more destructive, owing to their much smaller reserves of starch and nitrogenous substances as compared with broad-leaved trees. Oak, Beech, Poplar, and Willow are more attacked than

Ash, Elm, Maple, Sycamore, Birch, or Alder. When Oaks have been defoliated in spring by leaf-roller caterpillars, they can utilise their nutrient reserves and flush into leaf again in July; but when caterpillars have devoured most of the foliage of Scots Pine and Spruce, the recovery of the Pine is doubtful, and the Spruce dies. In Britain, the Larch often suffers severely from mining-moths and leaf-lice. Damage to young crops is more serious than to older poles and trees; and attacks in spring are worse than those in summer or autumn, after buds are formed for next year's growth. And if foliage alone be attacked, the damage may only be temporary; but when roots and cambium are badly injured, the sapling, pole, or tree usually dies. Injurious insects are, fortunately, not the most prolific kinds. Hard winters are not fatal to most insects, and may favour the increase of beetles (protected by their horny casing) by causing the death of many insectivorous birds. Naked larvæ without any protective covering are sensitive to damp cold weather, and are killed in large numbers when moulting their skins. Warm and dry weather, stumps remaining after heavy timber falls, sickly crops of all ages, and dominated or unhealthy trees, all form breeding-places for injurious insects, which then increase with rapidity. Bark- and cambial-beetles lay eggs in stems thrown or broken by wind, or in winter-felled trees left till late spring or summer, or in those already sickly from attacks of other insects on the foliage. Pine-weevils breed in the stumps of recently felled trees, and feed on neighbouring young plantations. Moths usually lay their eggs on backward crops growing on inferior soil, and unable to recover from the injuries of the caterpillars; and such favourable breeding- and feeding-places form centres from which noxious insects spread to other woodlands. Hence the need for careful tending; neglect of any one part of a wood is a danger to all of the timber-crops.

Natural Checks upon Injurious Insects.—Wet, cold weather while caterpillars are moulting their skins, and when beetles and moths are pairing, keeps down injurious insects. Before any appear in unusual numbers, the balance of nature must somehow have been disturbed; and when left to nature the balance is usually restored in 3 to 4 years, by predatory and parasitic insects increasing greatly, and bacterial and fungous diseases breaking out epidemically and almost exterminating the insect. But to await this natural readjustment may mean entire loss of the timber-crops. In mixed woods there are more insectivorous birds than in pure woods (of Conifers especially), and this tends to check excessive increase of noxious insects. So far as considerations of sport permit, all natural enemies of injurious insects should be preserved, the chief among which are the following:—

1. *Mammals*.—Bats devour cockchafer and moths; moles destroy

grubs and mole-crickets; shrew, hedgehog, weasel, pole-cat, stoat, badger, and fox devour beetles and pupæ.

2. *Birds*.—The most generally useful are the cuckoo (the only bird devouring hairy caterpillars), the starling, flycatchers, titmice, tree-creepers, swallows, owls, and most song-birds; then thrushes, blackbirds, rooks, gulls, plovers, the kestrel, buzzards, woodpeckers, sparrows and finches, crows, ravens, jackdaws and larks, which are of less use.

3. *Insects*.—Predaceous and parasitic insects on the whole do far more than either mammals or birds to keep injurious kinds in check. The *predaceous kinds* prey, often both as larva and imago, on the eggs, larvæ, pupæ, and adults of noxious insects; while the *parasitic kinds* generally lay their eggs on the eggs and in larvæ (less frequently in the pupæ or adults) of the injurious kinds, on which the maggots feed when they hatch out. The useful insects generally exist in woodlands in large numbers; and when noxious kinds increase abnormally, so also do the useful kinds that feed on them. The useful insects belong chiefly to the orders *Coleoptera* and *Hymenoptera*; then to the *Diptera*, *Neuroptera*, *Hemiptera*, and *Orthoptera*; while the *Lepidoptera* contains no useful genus, just as the *Neuroptera* contains no injurious genus, so far as concerns the forester.

(1) *Predaceous Insects*.—Among *Coleoptera*, predaceous kinds include tiger- or sand-beetles (*Cicindelidæ*), predaceous ground-beetles (*Carabidæ*), dung-beetles (*Staphylinidæ*), carrion-beetles (*Silphidæ*), nitid or shining-beetles (*Nitidulidæ*), thread-beetles (*Colydiidæ*), soft-beetles (*Malacodermata*, including gold-beetles, *Cleridæ*), and lady-birds (*Coccinellidæ*). *Clerus formicarius* and *Rhizophagus depressus* are two very useful beetles in Conifer woods, as they prey on the Pine-beetle. *Clerus formicarius* is easily recognisable by its large black head, black antennæ with red-brown tips, red-and-black thorax, and abdomen red at base and black behind, with two well-marked transverse white bands across the wing-cases. The dark-headed larva is rose-red, and consists of twelve segments, the first three of which have legs. The first segment has a horny plate above, and the second and third have each two small horny spots; the last joint is covered with a horny shield, and ends in two small knobs. Both beetle and larva feed on larvæ, pupæ, and adults of destructive tree-beetles; and the larvæ bore into the bark to hunt for prey. The beetle always seizes its prey behind the head. It is also the most useful of insects in keeping down bark-beetles (*Scolytidæ*). *Rhizophagus depressus* is only about $\frac{1}{3}$ of an inch long, bright rusty red, with finely-punctured lines on the wing-cases. The larva is about $\frac{1}{4}$ of an inch long; the head and prothorax are reddish, and all the other segments whitish above and reddish below. The last segment of the body is red-brown, with two knobs above and a small motor-appendage below. Both beetle and larva

live below the bark of Pine and Spruce, crawling along the tunnels bored by injurious insects, and feeding on their larvæ and pupæ. The beetle also preys on the larvæ of longicorn beetles.

Among the **Hymenoptera**, the digging or fossorial wasps (*Sphegidae*) are both predatory and parasitic. They kill or deaden caterpillars, beetles, plant-lice, &c., with their stings, drag them to their holes, and lay eggs inside them. Wasps in general (*Vespidæ*), and especially the hornet (*Vespa crabro*, itself injurious to Ash), prey on moths and flies; while ants (*Formicidæ*), which live in large colonies within their breeding-mounds, devour all sorts of injurious larvæ. Among the **Diptera**, the predatory flies (*Asilidæ*) breed mostly in sandy localities, and attack and suck many other kinds of insects; while the leech-shaped larvæ of the humming- or hover-flies (*Syrphidæ*) kill plant-lice by sucking. Among the **Neuroptera** the scorpion-fly (*Panorpa*), the camel-necked flies (*Rhaphidia*), the gold-eyed fly (*Hemerobia perla*), and the ant-lion (*Myrmeleon*) all prey on noxious insects (though the last also on useful ants); and several dragon-flies (*Libellulidæ*) as larvæ, nymphæ, and especially as adults, kill many noxious insects, including moths. Among the **Hemiptera**, scaly and other bugs (*Pentastomidæ*, *Reduviidæ*) prey on plant-lice. But the predatory kinds in these last two orders are not so numerous or useful as those in the first-named three orders.

(2) *Parasitic Insects* are the chief enemies of noxious kinds; and the most important are the ichneumon-, braconid-, and chalcid-flies of the **Hymenoptera**, and the parasitic-flies (*Tachinidæ*) belonging to the **Diptera**.—The *Ichneumonidæ* vary in size, but are usually long and thin. The abdomen is often stalked, and the female has a long egg-layer consisting of a thin borer enclosed within two lateral sheaths. The wing-veins are few in number, and only form distinctly-closed cells when there is a submarginal vein. The antennæ are many-jointed, and usually thin, seldom clubbed. The feet have usually five joints. *Larvæ* footless, smooth, generally white, soft, and tapering towards both ends. *Pupa* soft and white, with free limbs. *Adults* usually fly from May till August, and generally lay their eggs in the larger species of larvæ of noxious insects. Egg-laying sometimes also takes place in pupæ, and occasionally in adults; while minute species even lay eggs within eggs of injurious insects. *Generation* partly single, but often double, and sometimes manifold; and they increase enormously when hosts are numerous. The *Tachinidæ*, distinguishable from other flies by rough brush-like hairs on the abdomen, are chiefly parasitic as larvæ on the larvæ and pupæ of moths and saw-flies. The principal species is *Tachina fera*, which destroys large numbers of insects, and generally pupates outside the host, in or on the ground, the pupa being round or oval, and brown or black.

Preventive Measures against Insect Attacks consist in—

1. Only growing tree-crops suited for the given soil, situation, and climate.
2. Forming mixed woods in groups suited to soil, &c., rather than large pure woods.
3. Careful weeding of young plantations and thinning of all older woods.
4. Speedy removal of all thinnings and timber felled, and clearance or burning of the branches and brushwood left on felled areas.

Fig. 35.

Clear-felling of a Spruce-wood, mixed with Scots Pine and Beech (Saxony, 1900).

Conifers barked for protection against beetles, the bark being stacked and the brushwood piled in heaps for sale. Narrow rings of bark are left at ends and middle of each log, to prevent excessive cracking during seasoning.

5. Barking of all Conifer logs left lying in the woods after the end of April (Fig. 35).
6. Grubbing up Conifer stumps, if saleable for fuel; otherwise barking and burning them along with the brushwood, to make them unsuitable as breeding-places for Pine-weevils.
7. Encouraging the increase of insectivorous birds by hanging up nesting-boxes, and preserving, so far as practicable, all the different kinds of the natural enemies of injurious insects.
8. Rectifying as soon as possible any damage done in the woodlands (by wind, snow, fire, &c.).

9. Careful examination of the woods to see if injurious insects are present (Fig. 36), and instructing the woodmen how to examine decoy-stems left as traps for bark-beetles.

Fig. 36.

*A sample-plot of Scots Pine ringed with bands of patent tar to ascertain if the Nun-moth (*Liparis monacha*) is present (Saxony, 1900).*

Exterminative measures are needed when noxious insects are found to be increasing, by such indications as bore-holes in the bark, bore-dust or drops of resin, gnawed leaves, excrement, gradual thinning of the foliage in tree-crowns, or the presence of insectivorous birds in larger numbers than usual ; but these measures differ for beetles and for moths.

(a) **Extermination of Beetles.**—Many bark-beetles and weevils can be destroyed by felling and barking Conifer trees attacked, and burning the

bark containing the eggs, larvæ, pupæ, and often the adults also. Decoy-stems should be felled and placed before bark-beetles pair, because they go to sickly and recently felled trees before attacking healthy stems whose strong resinous outflow might kill their brood. Stems laid down in winter or early spring should be barked and removed in May and June, and fresh decoy-stems placed to catch any second brood in August. Dominated or suppressed, but still healthy poles or trees should be used in preference to half-dry moribund stems, not so likely to attract the egg-laying females. It is best to raise the decoy-stems off the ground on rests, so as to let the beetles breed on the lower side, which remains sappy when the upper half is dry. The branches should be lopped to check evaporation through the foliage, but can also be set as traps. Timber from any winter fall is always more or less infested with beetles, and should be removed *and barked* by May. Removal alone is not enough, because in the sawyard or elsewhere the broods hatch out and increase the number of beetles. Decoy-stems should be examined occasionally to see if they are acting well as traps for eggs. Small drops of resin or heaps of bore-dust near the punctures and bore-holes may show this, while pieces of bark cut off and inspected will show how far the young brood has developed. When the biggest larvæ are about half-grown the bark should be stripped and burned, because egg-laying is then completed. Cockchafer-grubs can be collected in nurseries, and the adult beetles of large kinds like cockchafers and longicorns can be shaken or tapped down from the crowns of young trees and hand-collected. The large Pine-weevil can be caught in sappy bark-traps put soft side downwards, and killed by treading on them or pouring boiling water over them; and smaller beetles may be trapped in bundles of brushwood or bark, which should then be burned.

(b) **Extermination of Moths.**—When caterpillars attack on any large scale, decoy-trees are of no use; nor is spraying with preparations of lime-water, sulphur, tobacco-juice, quassia, paraffin, carbolic acid, Paris green, London purple, &c., practicable in extensive woodlands, although easy and efficacious in nurseries by means of knapsack-sprayers. Hence it is mainly during the caterpillar stage that exterminative efforts are successful.

Hand-picking can be adopted for some hairy caterpillars (by workmen wearing old gloves to protect their hands), and for such as hibernate on the ground under moss, &c., or can be brought down by shaking the poles or tapping on tree-branches with padded mallets or axe-heads, or are found in any trenches dug. By shaking and tapping the Pine Span-worm caterpillars may be brought to the ground and collected—especially early in the morning and during cool weather, when they have a looser foothold on the foliage than during warm sunshine. The clusters of Lackey-moth caterpillars are also easily crushed or burned. Swine will devour pupæ on

the ground, *e.g.*, Pine Beauty and Pine Span-worm, but not hairy caterpillars, which only cuckoos eat. When severe attacks are confined to small areas, the migration of caterpillars may be prevented by digging narrow trenches (about 1 foot deep and with perpendicular walls) round the infested portions, and interrupting the leaf-canopy overhead. In these trenches holes, also with clean-cut upright sides, should be made here and there along the sole to catch the caterpillars and lessen their chance of escape; and similar ditches should be cut within the area isolated. But *grease-banding* with patent viscous tar is most efficacious for moth-caterpillars that spin down to the ground to moult, or that hibernate under moss, &c., as the tarry rings prevent them from reascending the stems to feed. Patent tar is only effective while soft and sticky, although its efficacy is dependent on the fact that at least one of the ingredients has a smell so repulsive to caterpillars that they will not cross the ring till it becomes hard and dry. It is therefore essential that the grease-bands should remain sticky throughout the whole of the caterpillar stage of the life of the moth—*i.e.*, for at least six to eight weeks—without the surface hardening. Before grease-banding the stem needs to be cleared of loose bark, to economise grease and make it adhere closely, a girdle of about 4 inches being cleared on the stems with iron scrapers at about breast-height, and care being taken not to damage the soft inner bark. This should be done in winter and early spring throughout areas known to be infested by moth-caterpillars hibernating under the moss or eggs laid on the stems. About the end of March or early in April the rings of patent tar should be applied before mild weather makes the eggs hatch out or the caterpillars resume feeding. The tar can best be laid on with wooden spuds about 1 to 1½ inch broad, and smoothed off with other spuds of equal breadth hollowed to a depth of about ¼th of an inch (Fig. 37), the crop being first thinned to remove superfluous poles or stems likely to attract the breeding moths, and to reduce the cost of grease-banding.

Eggs can only be collected and destroyed when laid near the ground, and even then many get overlooked. But a daub of patent tar kills egg-clusters of the Gipsy and the Pale Tussock moths.

The insects chiefly injurious in British woods and nurseries are the following, those that are sometimes very destructive

Fig. 37.

Spud and smoothing-stick (about ¼th real size).

being marked thus *, and afterwards described in detail (pp. 195 to 232):—

Classification, and Common and Scientific Names.	Destructive as	Trees and Parts of Tree chiefly attacked.
I. Beetles (Coleoptera). A. BARK-BEETLES, Scolytidae. a. Scolytini group. 1.* Large Elm-bark beetle, <i>Scolytus destructor</i> 2. Small do. <i>S. multi-striatus</i>	larva	Elm : stem.
b. Hylesinini group 1.* Large Pine-shoot beetle, <i>Hylesinus piniperda</i> 2.* Crutch Pine-beetle, <i>H. palliatus</i> 3.* Small Pine-shoot beetle, <i>H. minor</i> 4. Black Pine-cambial beetle, <i>H. ater</i> 5.* Ash-bark beetles, <i>H. fraxini</i> , <i>H. crenatus</i>	beetle, larva beetle larva	Scots Pine: shoots, stem. Pines: young bark near ground. Ash: stem.
c. Bostrichini group. 1.* The 2-toothed Pine-bark beetle, <i>Bostrichus bidens</i> 2.* Acuminate Pine-bark beetle, <i>B. acuminatus</i> 3. Large 6-toothed Pine-bark beetle, <i>B. sexdentatus</i> 4. Larch-bark beetle, <i>B. laricis</i> 5. 3-striped Wood-boring beetle, <i>B. lineatus</i> 6. Oak bark- and wood-boring beetle, <i>B. dispar</i>	larva " " " " "	Pines: stem, branches. Scots Pine: crown, branches. Pines: logs. Pines: stem, logs. Conifers: logs. Oak, Beech: stem, logs.
B. WEEVILS OR LONG-SNOUDED BEETLES, Curculionidae. 1.* Large Pine-weevil, <i>Hylobius abietis</i> 2.* Small banded Pine-weevil, <i>Pissodes notatus</i> 3. Pine-pole weevils, <i>P. piniphilus</i> , <i>P. pini</i> 4.* Beech leaf-mining weevil, <i>Orchestes fagi</i> 5. Oak leaf-mining weevil, <i>O. querci</i> 6. Willow, Poplar, and Alder weevil, <i>Cryptorhynchus lapathi</i> 7.* Crawling Hazel-weevil, <i>Strophosomus coryli</i>	beetle larva, beetle larva " " larva, beetle "	Conifers: bark of young plants. Conifers: bark of young plants. Scots Pine: stem. Beech: leaves. Oak: leaves. Softwoods: shoots, bark. Most trees: buds, shoots.

Classification, and Common and Scientific Names.	Destructive as	Trees and Parts of Tree chiefly attacked.
C. LAMELLICORN BEETLES, <i>Scarabæidæ</i>. 1.* Cockchafer or May-beetle, <i>Melolontha vulgaris</i> 2.* Summer-chafer, <i>Rhizotrogus solstitialis</i> 3.* Garden-chafer or Bracken-clock, <i>Phyllopertha horticola</i>	larva beetle	Roots of young plants. Leaves of trees.
D. LONGHORN BEETLES, <i>Cerambycidæ</i>. 1.* Musk-scented Willow Longhorn, <i>Aromia moschata</i> 2. Large Poplar Longhorn, <i>Saperda carcharias</i> 3. Small Poplar Longhorn, <i>S. populnea</i>	larva " "	Willow, Lime : stem. Poplars, Willows : stem. Poplars : branches.
E. SAWHORN BEETLES, <i>Buprestidæ</i>. 1. Green Sawhorn beetle, <i>Agrilus viridis</i>	larva	Beech, Oak : young stems.
F. LEAF-BEETLES, <i>Chrysomelidæ</i>. 1. Red Poplar-leaf beetle, <i>Lina populi</i> 2. Aspen-leaf beetle, <i>L. tremulæ</i> 3. Willow and Osier beetle, <i>Phratora vitellinæ</i>	larva, beetle " "	Poplars, Willows : leaves. Poplars, Willows : leaves, shoots. Willows, Poplars : leaves.
G. CLICK-BEETLES OR SKIP-JACKS, <i>Elateridæ</i>. 1* Striped or wire-worm click-beetle, <i>Agriotes lineatus</i>	larva	Roots in nurseries.
II. Moths (<i>Lepidoptera</i>). A. SPINNERS, <i>Bombycidæ</i> 1.* Puss-moth, <i>Cerura vinula</i> 2.* Hop-Dog or Pale Tussock moth, <i>Dasychira pudibunda</i> 3. Brown-tail moth, <i>Porthesia chrysorrhœa</i> 4. Lackey moth, <i>Gastropacha neustria</i> 5. Black Arches or Nun moth, <i>Liparis monacha</i> 6. Satin moth, <i>L. salicis</i> 7. Vapourer moth, <i>Orgyia antiqua</i>	caterpillar " " " " " "	Softwoods : leaves. Beech : leaves. Oak : leaves. Spruce, Pine : leaves. Poplars, Willows : leaves. Willow, Spruce, Pine : buds, leaves.
B. OWLET- OR NIGHT-MOTHS, <i>Noctuidæ</i>. 1.* Pine Beauty or Owlet-moth, <i>Trachea piniperda</i>	caterpillar	Pines : leaves.

Classification, and Common and Scientific Names.	Destructive as	Trees and Parts of Tree chiefly attacked.
C. SPAN-WORM MOTHS, <i>Geometridæ</i>. 1.* Winter moth, <i>Cheimatobia brumata</i> . 2.* Pine Span-worm or Bordered White moth, <i>Fidonia pinaria</i> 3. Mottled Umber moth, <i>Hybernia defoliaria</i>	caterpillar " "	Oak, Elm : leaves. Pines, Spruce : leaves Oak and hard- woods : leaves.
D. LEAF-ROLLER MOTHS, <i>Tortricidæ</i>. 1.* Green Oak Leaf-roller, <i>Tortrix viridana</i> 2.* Pine shoot-twister, <i>Retinia buoliana</i> . 3. Pine-bud moth, <i>R. turionana</i> . . 4. Pine Resin-gall moth, <i>R. resinella</i> .	caterpillar " " "	Oak : leaves. Pines : leading shoots. " buds. " shoots.
E. LEAF-MINING MOTHS, <i>Tineidæ</i>. 1.* Larch Leaf-mining moth, <i>Coleophora laricella</i> 2.* Larch Shoot-boring moth, <i>Argyresthia lavigatella</i> 3. Ash-bud moth, <i>Prays curtisella</i> . .	caterpillar " "	Larch : leaves. Larch : leading- shoot. Ash : leading-bud.
F. WOOD-BORING MOTHS, <i>Cossidæ</i>. 1.* Goat-moth or Augur-worm, <i>Cossus ligniperda</i> 2.* Leopard-moth, <i>Zeuzera æsculi</i>	caterpillar	Broad-leaved trees : stem.
G. CLEARWING MOTHS, <i>Sesiidæ</i> . 1. Hornet clearwing-moth, <i>Sesia apiformis</i>	caterpillar	Poplars : stem.
III. Skin-winged Insects (<i>Hymenoptera</i>). A. SAWFLIES, <i>Tenthredinidæ</i>. 1.* Pine Sawfly, <i>Lophyrus pini</i> 2.* Red Sawfly, <i>L. rufus</i> 3.* Large Larch Sawfly, <i>Nematus Erichsoni</i> 4. Small Larch Sawfly, <i>N. laricis</i>	caterpillar " "	Pines : leaves. Larch : leaves.
B. WOOD-WASPS, <i>Siricidæ</i>. 1. Large Yellow Wood-wasp, <i>Sirex gigas</i> 2. Steel-blue Wood-wasp, <i>S. juvencus</i>	larva	Conifers : stem.
C. GALL-WASPS, <i>Cynipidæ</i>. 1. Oak-apple Gall-wasp, <i>Cynips querci</i> 2. Oak Marble-gall wasp, <i>C. Kollari</i>	larva	Oak : leaves and twigs

Classification, and Common and Scientific Names.	Destructive as	Trees and Parts of Tree chiefly attacked.
IV. Two-winged Insects (Diptera). A. GALL-GNATS (Cecidomyiidae). 1. Large Willow-twigg midge, <i>Cecidomyia salicis</i> 2. Small Willow-stem midge, <i>C. saliciperda</i> 3. Osier shoot-tip gall-midge, <i>C. heterobia</i> 4. Beech-leaf gall-midge, <i>C. fagi</i> 5. Larch-bud gall-midge, <i>C. Kellneri</i>	larva " " " "	Osiers: young twigs. Willows: young stems. Osiers: shoot-tips. Beech: leaves. Larch: buds.
V. Half-winged Insects (Hemiptera). (1) With similar fore- and hind - wings (Homoptera) A. PLANT-LICE (Aphidae). 1.* Big Spruce-gall and Larch aphid, <i>Chermes abietis-laricis</i> 2. Small Spruce-gall aphid, <i>Ch. coccineus</i> , <i>Ch. strobilobius</i> 3. Silver Fir aphid, <i>Ch. piceæ</i> 4. Pine aphid, <i>Ch. pini</i> 5. Elm woolly gall - aphid, <i>Schizoneura ulmi</i>	all stages " " " "	{ Spruces: base of twigs. { Larch: leaves. Spruces: twig-tips and buds. Silver Firs: stem, leaves. Pines: twigs, branches. Elm: shoot, leaf.
B. SCALE-INSECTS (Coccidae). 1.* Felted Beech - scale, <i>Cryptococcus fagi</i> 2. Felted Ash-scale, <i>Apterococcus fraxini</i> 3. Felted Willow-scale, <i>Chionaspis salicis</i>	all stages " "	Beech: bark. Ash: bark. Willow, Ash: bark.
(2) With different wings (<i>Heteroptera</i>): Bugs are not injurious in woodlands, and some predaceous kinds are useful		

DESCRIPTIVE NOTES OF INSECTS SOMETIMES VERY DESTRUCTIVE IN BRITAIN.

(Those marked thus * in the above Table.)

I. BEETLES (Coleoptera)

A. BARK-BEETLES (Scolytidae).

* The large Elm - bark beetle, *Scolytus destructor* (Fig. 38), often does great damage to Elm and Ash. Beetle $\frac{1}{8}$ to $\frac{1}{4}$ in. long, black with chestnut-brown shield-wings, and reddish-brown feelers and legs. The ♀

bores through the bark in June, forming a vertical tunnel 3 or 4 in. long in which eggs are laid. Larvæ hatch out in autumn and feed on the inner bark (forming secondary-galleries) till the following spring or early summer, when they pupate and emerge through the bark as adults either in August or the following spring.

Fig. 38.

Elm-bark Beetle, magnified five times.

After pairing, the ♀ again bores into the bark and lays her eggs, and so on till the stem is girdled, and the tree becomes diseased or killed. Trees from which beetles have emerged look as if riddled with shot; and fine sawdust will be found on the bark or at the foot of the tree. They generally attack healthy and vigorous stems, as well as unhealthy trees. In Britain usually only a few beetles emerge in August. *Extermination*.—Moribund trees attacked are best felled and barked late in July or early in August, and the bark burned. The rough outer bark of trees showing bore-holes can

be spoke-shaved to kill the larvæ by exposure, and by the flow of sap; and insecticide washes can then also be applied.

* **The large Pine-shoot beetle, *Hylesinus piniperda*** (Fig. 39-41), is very destructive in Pine-woods, attacking plantations of nearly all ages. Far less damage is done by the larvæ than by the beetle. Owing to strong resin-flow from healthy stems, it chiefly attacks felled timber or sickly plantations, healthy trees being only attacked after excessive increase. Attacks are usually worst along green lanes and in pole-woods near timber-depots or saw-mills. The beetle is $\frac{1}{2}$ to $\frac{3}{8}$ in. long, almost cylindrical, at first reddish-brown, then glossy black or dark-brown, thorax black, feelers and legs reddish-brown. The shield-wings have longitudinal rows of fine punctures, with the spaces between wrinkled with punctures and small knobs, and having a row of little knobs with brush-like tufts of thick hair. Beetles emerge from their pupal-chamber or their winter quarters late in March (in dry warm years) or in April, pair and lay eggs in newly-felled stems or stacked fuel, sickly trees, or fresh stumps of Pine, Spruce, and Larch. After pairing, the ♀ bores under some bark-fissure, and lays eggs along a vertical main-gallery about 4 in. long. Boring and egg-laying continue for 3 to 5 weeks, up to 100-120 eggs being laid closely in niches to right and left along the edges of the main-gallery, the bore-hole being sometimes marked by resin-outflow. In 2 to 3 weeks the larvæ hatch out and eat sinuous galleries on each side of the main-gallery, and about 8 weeks later pupate for about 14 days in pupal-chambers formed in the bark; and the beetle usually issues in June, about 11 to 12 weeks after the

egg-laying (or later if spring cold and backward), the exit-holes making stems sometimes look as if riddled with snipe-shot. The beetles either pair at once and produce a second generation within the year, or else bore into young Pine-shoots and breed during the warmer months or in the following spring, the beetle hibernating in bark-fissures or under moss, or boring into the thick bark near the ground. Warm weather favours a double generation. Beetles of the second generation and any

Fig. 40.

Bark showing main and larval galleries and 2 air-holes—natural size. The ♂ keeps near the entrance-hole, while the ♀ bores the gallery.

Fig. 39.

Hylesinus piniperda, magnified seven times.

Fig. 41.

Shoot of Scots Pine, showing entrance-hole, and (where slice removed) boring of a beetle, $\frac{2}{3}$ natural size.

of the first generation late in developing bore into the tops of the youngest Pine-shoots just below the buds (entrance-hole generally noticeable by a shell of resin round it), feed on the pith, and either turn and leave again by the same hole, or else make a special exit-hole. Shoots thus hollowed break and fall during storms, and the trees attacked look as if pruned. With frequent attacks, the crowns assume a pointed pyramidal shape, from continuous loss of side-shoots, and often become stag-headed.

Prevention and Extermination.—The best measures are keeping the woods clean, removing all windfall and sickly trees, or stems having bore-dust lying round them, or on which white resin-shells or entrance-holes in thick bark indicate that they are already infested. From decoy-stems placed here and there in spring and summer, the bark should be peeled and burned at the proper time. Winter-felled timber may thus be used; but if not removed from the woods by the end of May, it ought then to be barked. Collecting and burning hollowed shoots lying scattered on the ground is of little use, as the beetles emerge before the twigs break.

* **The Crutch Pine-beetle**, *Hylesinus palliatus* (so called from the main-galleries beginning with a boot-shaped or crutch-like bend), often attacks along with *H. piniperda* in Scotland. Only about $\frac{1}{2}$ in. long, it is often overlooked, as it can breed in stems not freshly felled.

* **The Small Pine-shoot beetle**, *Hylesinus minor*, $\frac{1}{7}$ to $\frac{1}{8}$ in. long, having uninterrupted knob-like tubercles with brush-like tufts at the ends of the shield-wings, and more red-brown than deep brown or black, is also found with *H. piniperda* and *H. palliatus* in Scots Pine and Spruce pole-woods and middle-aged crops. It breeds in sickly trees.

* **The black Pine-cambial beetle**, *Hylesinus ater*, about $\frac{1}{8}$ to $\frac{1}{6}$ in. long, and black with red-brown feelers and feet, only does damage as a beetle, attacking 2- to 6-year-old Pine plantations. Common in Britain, it is not very injurious.

* **The Ash-bark beetle**, *Hylesinus fraxini* (Fig. 42), is destructive all over Britain, and often bores into healthy Ash-poles and trees, which soon sicken, then become much infested, and are quickly killed.

About $\frac{1}{2}$ in. long, light to dark-brown, wing cases with five longitudinal punctured lines. Beetles emerge from their winter quarters in late April or early May, and lay eggs in the stem and branches of Ash-trees or in Ash-logs lying in woods or parks, which are probably their chief breeding-places. From 20 to 60 eggs are laid along each arm of the 2-armed mother-gallery, and in a few days the larvæ hatch out, reddish or purplish at first, with brown head and jaws, legless, transversely furrowed, and tapering to the tail. After feeding for about ten weeks, they pupate either in the bark or the sapwood. The young beetles emerge in August (their exit-holes making the trees look as if riddled with shot), and at once attack neighbouring Ash-trees or freshly-felled logs, where they form galleries and feed during the autumn, then remain dormant in winter, and feed again in March and April, before emerging to pair. *Prevention* consists mainly in planting Ash only on really suitable soil, and *Extermination* in removing logs before August, in cutting out sickly Ash-poles and trees by February and March, in leaving decoy-logs in parks, and in barking all infested stems in June and July and burning the bark.

The black Ash-bark beetle, *H. crenatus*, $\frac{1}{8}$ to $\frac{1}{4}$ in. long, attacks trees injured by *H. fraxini*, and breeds there till the tree dies.

* The 2-toothed Pine-bark beetle, *Bostrichus bidens*, is the commonest *Bostrichus* in our woodlands. It chiefly attacks Scots Pine, but also other Pines, Spruce, and Larch, its attacks being mainly confined to 10- or 12-year-old plantations, or to the thin-barked crowns and branches

Fig. 42.

Portion of young Ash-trunk with borings of *H. fraxini*, $\frac{2}{3}$ nat. size.

of poles and trees. It sometimes does extensive damage in plantations, and even interrupts the canopy of old Pine-woods.

Beetle about $\frac{1}{16}$ in. long, black, glossy, and covered with fine hairs. The shield-wings are usually dark-brown, with rows of fine punctures. In the ♂ both shield-wings have broad, flat indentations, on the upper edge of each of which there is a large, hooked, tooth-like process (hence *bidens*); but the ♀ has not these indentations and tooth-like processes. Beetles appear in May and June, and lay eggs on the thin bark of young

plantations, pole-woods, and living or dead branches of Pine-trees. The larvæ hatch out in June and July, feed about 4 weeks, pupate in July and August, and emerge as beetles in August and September. The main-galleries radiate in star-shape, but differ from those of *B. chalcographus* by greater irregularity, by both the main- and the larval-galleries entering more or less into the sapwood, and by the pupal-chamber being mainly in the sapwood. The first generation usually emerges in July and proceeds to pair and produce a second generation, appearing in September. This second generation of beetles usually hibernates till the following May or June; but in warm dry seasons it can produce a third generation, which hibernates as larvæ.

Prevention and Extermination consist in keeping the woods clean, thinning and removing sickly poles, and laying down traps of small thin-barked branches and twigs (such as may be cut from decoy-stems set for larger bark-beetles), and then burning them after egg-laying is finished in June. Seedlings or saplings attacked should be pulled up and burned, and infested poles felled and barked, and the bark burned.

* **The Acuminate Pine-bark beetle**, *Bostrichus acuminatus*, is sometimes destructive in the crowns of middle-aged and maturing Scots Pine woods. The beetle is about $\frac{1}{8}$ to $\frac{1}{6}$ in. long, and brown with yellowish-grey down. The shield-wings have regular rows of punctures, and are sharp pointed where they meet near their upper end (hence *acuminatus*); and each shield-wing has there 3 tooth-like processes, the third being the largest. Beetles fly in April and May, when the ♀ lays eggs high up in the crown of old Scots Pine. The brood-galleries are stellate, with 3 to 5 arms radiating from a large pairing-chamber, and biting deep into the sapwood. The larval-galleries are mostly in the cambium, confused, irregular, often crossing each other. The beetles emerge in July and August, pair, and produce another brood, which emerge as beetles in autumn, hibernate under the bark (along with stragglers of the summer brood), and pair in the following spring. *Prevention and extermination*.—Fell and remove mature timber before spring is far advanced, and thin out sickly trees in old woods. As the eggs are laid high up in the crowns of old trees, it is difficult to trap this beetle in decoy-trees.

The large 6-toothed Pine-bark beetle, *Bostrichus sexdentatus*, largest of the bark-beetles, $\frac{1}{4}$ to $\frac{1}{2}$ in. long, glossy black or dark-brown with yellow hairs, but not very destructive or common, generally lays its eggs in freshly-felled timber, windfalls, and fuel-stacks, and mostly attacks old thick-barked Scots Pine when felled, but also woods from 20 to 30 years of age upwards.

The Larch Bark-beetle, *Bostrichus laricis*, $\frac{1}{7}$ to $\frac{1}{6}$ in. long, and usually dark-brown, is often found in Conifer-woods, but chiefly (despite its name) on

Pines or Spruce, and sometimes Larch and Silver Fir. It chiefly attacks poles, tree-tops, and stacked fuel.

The Wood-boring Bark-beetle, *Bostrichus lineatus*, is cylindrical, blackish, $\frac{1}{8}$ to $\frac{1}{6}$ in. long, with dull yellow-brown elytra, antennæ, and legs, and three dark longitudinal stripes along each shield-wing (hence *lineatus*), but has no tooth-like processes at their ends. In Scotland this beetle chiefly attacks recently-felled Scots Pine, Spruce, and Larch, and only exceptionally poor standing crops, and often riddles the wood with holes; but as the borings are mostly confined to the sapwood, the damage is not great, though it spoils poles for cellulose-making.

The Oak bark- and wood-boring beetle, *Bostrichus dispar*, black, with reddish feelers and legs, ♀ $\frac{1}{8}$ in., ♂ $\frac{1}{12}$ in. long, elytra well rounded at ends, and with rows of deep punctures, mostly attacks Oak and Beech, but also attacks other hardwoods, Birch, and Alder. The larvæ often kill off Oak saplings and transplants, and the beetle sometimes bores into and breeds in the stems of sickly old Oak, Beech, or timber lying on the ground, and spoils the timber. Trees or saplings infested show bore-dust on the ground.

B. SNOUTED WEEVILS (Curculionidæ).

* **The large Pine-weevil**, *Hyllobius abietis* (Figs. 43, 44), is the most destructive insect in our woodlands, though the damage is only done during the adult stage. It attacks young plantations of Pines, Spruce, Larch, Douglas Fir, and Silver Fir up to about 5 or 6 years old, and gnaws the bark, thus causing an outflow of resin in scab-like patches. Whole plantations are sometimes ruined, especially in warm, dry seasons. When the bark thickens and hardens there is less risk of damage, and plantations of 8 to 10 years are fairly safe. It sometimes attacks older trees, but the wounds soon get coated with resin and heal up. As it breeds in fresh sappy stumps, it is only found where Conifers have been recently felled. Weevil about $\frac{1}{3}$ to $\frac{1}{2}$ in. long, stoutly built, convex in shape, deep red to dark-brown or black, and having a long thick snout, with feelers springing from near its tip. It is marked with clusters of yellow scales or hairs between the eyes, on the sides of the thorax and abdomen, and on the elytra. These yellow patches look like cross-bands on the elytra, and are very distinct when the beetle emerges, but gradually become fainter. The beetles live two years or more, so that those recently emerged (distinctly marked) and older beetles (faintly marked) that have been out for some considerable time, as well as larvæ in every stage of development, may all be found simultaneously. Beetles appear from April till June, and crawl or fly to fresh Conifer falls, and lay eggs in the sappy stumps and roots. Pairing and reproduction continue in summer and autumn, as long as fresh stumps are available for breeding-

places, the eggs being laid singly on roots of $\frac{1}{2}$ in. diameter upwards, or sometimes in sawdust heaps near sawmills in the woods. In about 4 weeks they hatch out and bore in the dead cambium, but later enter the sapwood and form long winding galleries, trending downwards and sometimes 3 ft. long, at the end of which the pupal-chamber is formed. The yellowish-white larvæ have a large brown head, are curved or bent

Fig. 44.

The large Pine-weevil (Hylobius abietis).

- a. Beetle (slightly magnified).
- b. Larva (natural size).
- c. Pupa (natural size).

Young Spruce gnawed by the large Pine-weevil (Hylobius abietis), natural size.

a. Parts gnawed.

b. Parts undamaged.

by ventral contraction, and are about $\frac{1}{2}$ to $\frac{3}{4}$ in. long. When full grown, in autumn they hollow out their pupal-chamber in the sapwood, seal it up with bore-dust and wood-chips, and hibernate as larvæ till the following June, when they pupate and emerge as beetles about three weeks later, the development from egg to beetle thus occupying about 15 months. Beetles emerging in July and only partially reproducing themselves are very destructive in the following spring. They begin to hibernate from about the end of August till autumn, in thick grass or

weeds, stumps, logs, or dead branches. Early in autumn, females laying eggs often gather in large numbers in such places, and reappear in spring to pair again. *Prevention and Extermination.*—Extensive clear-felling of mature Conifer-crops and heavy windfalls, especially near young plantations, always increases this destructive weevil. Though seldom practicable, the best way of preventing attacks is to grub up all the stumps and roots as fuel; and where this can be done, there is little danger. Felling the timber by cutting through the main roots with an axe and pulling over the tree is not sufficient, as many thick roots remain in the ground.

When weevils are numerous the stumps can be used to trap the eggs, and then grubbed in late summer, after the eggs have been laid, or in the early spring. Where young plantations are to be made, it is best to peel the bark from stumps and roots so far as practicable, burn the area, heaping all the rubbish over the stools to dry them as much as possible, and let the land lie fallow for one or two years after a clear fall of timber. If the fall be at once replanted without thorough burning or removing the stumps and big roots, then breeding-places and feeding-grounds are both provided for the beetle.

In plantations where the weevils appear, bark-traps should be laid with pieces of fresh Spruce or Pine bark, put with the soft inner side next the ground, and weighed down with stones; or freshly cut Pine or Spruce poles may be cut into faggots about 3 ft. long, and a strip of bark about 2 in. broad peeled off lengthways, before laying them down with the barked part on the ground. The beetles, attracted by the fresh resinous odour, attack the cambial layer of these decoys, and can be collected daily. They will also feed on bundles of fresh Pine branches, and can be collected by being shaken out on sheets spread on the ground to catch them as they fall. Handpicking by boys and girls is also useful. When collected, they can be killed by pouring boiling water over them.

* **The small banded Pine-weevil**, *Pissodes notatus* (Fig. 45), $\frac{1}{4}$ to $\frac{1}{2}$ in. long, and with feelers springing from near the middle of the snout, is often found along with the large Pine-weevil, and is very destructive to Pines, Spruce, and Larch. It attacks both as larva and beetle, the larva being very destructive, in boring in the bark, and between bark and sapwood, and gnawing away parts where the bark is thin. The weevil does not gnaw, but pushes its snout through the bark into the sapwood near the foot of young plants 3 to 6 years old, and sucks the sap, a badly attacked stem looking as if it had been there pricked all over with a needle and beads of resin had oozed out.

Beetle $\frac{1}{4}$ to $\frac{1}{2}$ in. long, dark red-brown, irregularly covered with small scale-like greyish-white hairs; on thorax 6 to 8 plainly marked small white or yellowish dots; elytra with two broad rusty-red transverse bands

bearing white and yellow scales, the upper band being interrupted at the junction of the wings; snout long and thin, with feelers springing from near the middle. Beetles swarm in April and May, and from April to September lay eggs (often in small clusters), mostly under the whorls of 3- to 8-year-old Pines, and in Pine-cones and the bark of sickly poles. The yellowish-white brown-headed larvæ on hatching out tunnel down-

Fig. 46.

Fig. 45.

The small Pine-weevil (Pissodes notatus).

- a. Beetle (magnified four times).
- b. Beetle (natural size).
- c. Larva (magnified twice).
- d. Pupa (magnified twice).

Young Pine-stem barked to show the pupal-chambers and exit-holes of Pissodes notatus (half natural size).

wards, eating sinuous star-shaped galleries in the cambium, which terminate in a pupal-chamber formed in the sapwood. On entering this to pupate, the vacant space is filled up with bore-dust and wood-chips (Fig. 46), and several pupæ may often be found embedded just below a branch-whorl. The beetle emerges by a circular hole in August or later, pairs and reproduces itself, then hibernates from November under moss or in bark-fissures, and reappears for pairing again in April and May.

The generation is usually annual, though there may be three in two years. *Extermination*.—When young shoots of plants infested by the larvæ droop and look sickly about July, they should be pulled up and burned; and if persevered in for several years in succession, this almost completely exterminates the beetle. Poles attacked should also be felled and barked; but it is much easier to recognise attacks on young plants than on poles.

* **The Beech leaf-mining weevil**, *Orchestes fagi*, often swarms in Beech-woods, sometimes does great damage to the leaves and flower-buds, and is very destructive in defoliating Beech-trees. Weevil only $\frac{1}{2}$ to $\frac{1}{10}$ in. long, black, and covered with fine grey hairs; elytra with rows of coarse punctures; antennæ and legs are light-brown; snout, when not in use, bent back under the thorax; thighs of hind-legs thick, for springing. The ♀ bites small holes on the lower surface of young leaves in spring, and lays one egg in each hole near the midrib. The larvæ hatch out in 2 to 3 weeks, and mine in the leaf-substance, forming whitish galleries (which soon turn brown), increasing in breadth as the grub grows in size, and damaged leaves turn brown, as if nipped by frost. The pupal stage is passed in the leaf. The beetles emerge in June, feed on the leaves and nut-cupules till autumn, then descend and hibernate under dead leaves on the ground. *Prevention* is hardly possible in woodlands; but the attacks are least in mixed woods, where insectivorous birds are always most plentiful. Ornamental trees may be sprayed with arsenic solution formed by stirring $\frac{1}{2}$ lb. Paris-green paste in 100 gallons water, and adding 1 lb. lime. If this is not successful, infested leaves should be picked in May and burned, and beetles shaken down and killed in June.

The Oak leaf-mining weevil (*Orchestes quercii*) does somewhat similar damage to Oak foliage.

5. **The Willow, Poplar, and Alder-weevil**, *Cryptorhynchus lapathi*, about $\frac{1}{2}$ in. long, and strongly marked by having its elytra dark-brown for their first two-thirds, and white-scaled for the last third, gnaws the bark of young shoots of old Willow and Poplars and young Alder-trees; but its larvæ do far more damage by burrowing into the wood and forming galleries from which the bore-dust is cast out at the entrance. Beetles can be shaken down from trees in May, and badly infested branches or trees cut in July and burned.

* **The Crawling Hazel-weevil**, *Strophosomus coryli*.—The larva is chiefly found on Hazel, Oak, Beech, and Birch, but also attacks other broad-leaved trees and Conifers, and hollows out the buds before gnawing the young shoots. The crawling weevil also feeds in spring on the edges of needles and the bark of young Pine and Spruce, especially 2-year-old seedlings, and does much damage when occurring in large numbers.

Beetles $\frac{1}{2}$ to $\frac{1}{4}$ in. long, almost spherical, brownish-grey with greyish metallic sheen; basal junction of elytra black, without hairs or scales;

antennæ and legs rusty-red ; rostrum with fine groove along middle. It has no flying wings, but crawls up stems, pairing and egg-laying about June. *Prevention and Extermination.*—In nurseries beetles may be shaken down and collected. They drop to the ground with slight shaking, and crawl quickly away ; but grease-banding stems with patent tar prevents their reascending.

C. LAMELLICORN BEETLES (Scarabæidæ).

* **The Cockchafer, May-Beetle, or White-grub, *Melolontha vulgaris*** (Fig. 47), as a beetle feeds on the leaves and flowers of Oak chiefly, and

Fig. 47.

The Common Cockchafer (Melolontha vulgaris).

- a. Beetle (male—natural size). c. Feeler of female (6 lamellæ—magnified four times).
 b. Feeler of male (7 lamellæ—magnified four times). d. Grub (natural size).
 e. Pupa (seen from below—natural size).

other broad-leaved trees, sometimes almost defoliating them, while among Conifers it mainly eats soft tufts of Larch-needles and male flowers of Pine. But it is most destructive as a voracious grub in loose soil, from the second year onwards gnawing the roots of young plants, and especially of perennial grasses, weeds, and Conifer seedlings, so that the last soon die off, while older plants sicken when attacked. In seed-beds the well-prepared soil attracts the ♀ when laying eggs, and on falls of Scots Pine on sandy soil grubs are often very destructive.

Beetle, 1 to 1½ in. long; thorax black or reddish-brown; elytra and legs ruddy-brown; the elytra with 5 longitudinal ridges, the 4 hollows between which are covered with fine hairs; abdomen black, with 5

triangular white spots on each side, and gradually terminating in a broad, elongated, pointed tail; antennæ with 10 joints, the laminae 7-jointed and feathery on ♂, but 6-jointed, smaller, and narrower on ♀. The full-grown larva or *grub* is $1\frac{1}{2}$ to 2 in. long, thick, fleshy, dirty-white, the tail-end swollen, darker in colour, and generally bluish from the excrement showing through. It has a thick, yellow-brown head, strong biting jaws, and 6 long feet attached to the thorax. The pupa is brownish-yellow, with two horny processes on the last abdominal segment. The beetle flies in May and June. After pairing the ♀ seeks open spaces with loose soil, and lays in some 70 creamy-white eggs about the size of hemp-seed, in clusters of 10 to 30 at a depth of 2 in. or more below the surface, then reascends and soon dies. The grubs hatch out nearly 4 weeks later, and during the first year feed on grass-roots, decomposing foliage, &c. In autumn they burrow deeper, but reascend nearer the surface in spring and feed on the roots of plants until autumn, when they again hibernate, and reascend in the third spring to once more feed as grubs on the roots of young plants; and the nearly full-grown grubs then do most damage. Again (for the third time) they hibernate as grubs after burrowing deep into the soil, and in spring reascend and feed for a short time. In June, three years after hatching out, they burrow deep into the soil and pupate in an oval hole with smooth hard walls, and after 4 to 8 weeks of pupal rest the beetle comes out soft and white, but gradually hardens and deepens in colour. Without coming to the surface it hibernates below ground, and only emerges in the following May from a hole such as is made with the point of a walking-stick. In Britain four years are needed for normal generation (though in warm countries generation takes three years only), and swarms therefore reappear every four years, only stragglers being seen in the intervening years. *Extermination*.—So far as practicable, the ♀ should be given no favourable opportunity of laying eggs on blank spaces with loose soil when chafer-years are expected; and dibbling is then preferable to pit-planting on sandy soil. Where chafers abound, nurseries should not be formed near pastures from which beetles may fly to lay eggs. But the best protection is to hang up nesting-boxes for starlings all round the nursery. Natural remedies fail, however, to check the periodic chafer-years, when the beetles should in the early morning be shaken down from young poles and collected and killed by pouring boiling water over them, or by dipping the sacks full of them into hot water, such collections being made before the beetles begin egg-laying, and simultaneously over the whole area infested. Grubs can only be exterminated in nurseries where noticed by the withering of seedlings attacked, when each grub can be dug up. They can also be trapped with turf-sods about 10 in. broad and 6 or 8 in. thick being laid, grassy side downwards, on the ground; or

heaps of turf-humus, dung, &c., may also be employed; and grubs collecting under these can be gathered and destroyed. Or potatoes may be placed below ground and examined daily. — Equally destructive are the two smaller species, the * **Summer-Chafer**, *Rhizotrogus solstitialis*, and the * **Garden-Chafer or Bracken-clock**, *Phyllopertha horticola*, and all three have increased during the last ten years. They are easily distinguished from the Cockchafer, as the Summer-Chafer is about $\frac{3}{4}$ in. long, reddish-brown, and slightly hairy, and the Garden-Chafer about $\frac{1}{4}$ to $\frac{1}{2}$ in. long, the front part of the body greenish with metallic sheen, and the elytra reddish-brown; and they both appear in June and July, about a month later than the Cockchafer; but the grubs are very similar

when young, and difficult to identify, though they are smaller when full-grown. The habits of the grubs are very similar to those of the Cockchafer.

D. LONGHORN BEETLES (Cerambycidae).

* **The Musk-scented Willow Longhorn**, *Aromia moschata*, is a thin beetle about 1 in. long, with glossy metallic sheen varying from rich blue and green to coppery red, with a strong spine on each side of thorax, the feelers of ♀ shorter, and those of ♂ much longer than the body. The larva is very destructive by boring into old pollarded Willows, and also into Lime-trees.

The large Poplar Longhorn, *Saperda carcharias* (Fig. 48), the larvæ of which chiefly infest Poplars and Willows up to about 20 years old, is about 1 to 1½ in.

long (with antennæ of about same length), clay-grey to yellowish-brown, and with thorax and wing-cases covered with shining black spots.

The small Poplar Longhorn, *Saperda populnea*, about $\frac{1}{2}$ in. long, and black, with yellow or yellowish-grey hairs, often infests the branches of young Poplars without doing them much harm.

E. SAWHORN BEETLES, Buprestidæ.

The Green Saw-horn beetle, *Agrilus viridis*, about $\frac{1}{4}$ in. long, and usually blackish with a lustrous metallic blue, green, or olive sheen, appears in June and July, when the ♀ lays eggs singly or in clusters of 2 or 3 on the bark near the base of young Beech or Oak. The larvæ hatch out 4 to 6 weeks later, feed on the cambium and kill saplings or make them sickly and cankered-like, hibernate inside the stems for two winters, then pupate in the cambium or the sapwood in the follow-

Fig. 48.

Large Poplar Longicorn.

- a. Beetle (natural size).
- b. Larva (natural size).
- c. Head of larva (magnified).

ing April or May, and emerge from a half-moon hole (☾) with flat side above during June and July (generation biennial). Plants attacked should be pulled up and burned before the beetles emerge in June.

R. LEAF-BEETLES (Chrysomelidae).

The Red Poplar-leaf beetle, *Lina populi*, feeds both as beetle and larva on Poplar, Aspen, and Willow foliage, and sometimes seriously retards the growth of Osier-beds. The beetle is $\frac{1}{2}$ in. long, with blackish-blue body, and brick-red elytra tipped with black at upper end; antennæ short, compressed, and thickening towards ends; larvæ, 6-footed, dirty-white, with numerous black spots, and two white lateral processes on the second and third segments; pupa, yellowish-brown, with regular black spots and bands, and is somewhat pear-shaped, hangs head-downwards, and attached to leaves by a sharp-pointed tail-end. The beetles fly in May and June, and the ♀ lays 100 to 150 eggs in clusters of 10 to 12 on the foliage of young saplings, stool-shoots, and suckers. The larvæ hatch out in 4 weeks, feed for 4 weeks, then pupate on leaves, and emerge as beetles about the end of August. In October they hibernate under moss or dead leaves, and reappear and pair in the following May (generation simple, annual). Beetles may be shaken down from trees while pairing in May or June, or else from August till October before hibernating. Spraying Osier-shoots and the soil beneath them with insecticides is often effective.—**The Aspen-leaf beetle, *Lina tremulæ*,** is very similar but only $\frac{1}{3}$ in. long, and has no black tips to the elytra. It is somewhat more destructive, as it attacks the shoots while still young and soft.—**The Willow and Osier beetle, *Phratora vitellina*,** $\frac{1}{4}$ to $\frac{1}{5}$ of an in. long, bronze green or coppery, oblongly-oval, and having elytra with rows of fine punctures, appears from late April to June, and lays large oblong eggs in clusters of about 10 or 12 on the lower side of Osier, Willow, and Poplar leaves. The larvæ hatch out in 4 weeks, and skeletonise both the spring and the summer flush of leaves before pupating in the ground. The beetles emerge in August, feed for some time, then hibernate in the ground, bark-fissures, or any other hiding-place. The generation is usually single, though sometimes early-comers in August pair and produce a second brood before hibernating.

G. CLICK-BEETLES or SKIP-JACKS (Elateridae).

* **The Striped Click-beetle, *Agriotes lineatus*,** is the commonest and the most destructive species (Fig. 49).

Beetle $\frac{3}{4}$ in. long, with a wing-expanse of fully $\frac{1}{2}$ in.; thorax tawny; elytra brown, with yellowish-brown lines; antennæ reddish-yellow; legs brown. The "wire-worm," or larva, is $\frac{3}{4}$ in. long, very shiny, and yellow (chestnut when dead), with a few hairs on its body, 3 pairs of 4-jointed legs on the first three segments, and a swelling on the lower surface of the terminal segment. It has strong jaws for biting through roots. Beetles,

found under stones, in grass-roots, on grasses, flowers, and trees, in hedges, &c., fly in July and August, and (like the cockchafer) lay eggs in nurseries and wherever the soil has been loosened. Some beetles hibernate in sheltered places, and pair in the following May and June; and the wire-worms hatching out live in the earth, near the plant-roots on which they feed. After feeding for 3 to 4 years, according to circumstances, the larva goes deep down and pupates in July in a small oval earthy cocoon, from which the beetle emerges in 2 or 3 weeks. *Prevention and Extermination.*—Plovers, rooks, starlings, and jackdaws help to keep them in check, and nitrate of soda, dressings will prevent egg-laying on nursery-beds; but once part of a nursery is infested, it is best to sow

Fig. 49.

Wire-worms.

1. *Agriotes lineatus* (natural size).
- 1a. *Agriotes lineatus* (magnified).
3. Wire-worm, larva of *Agriotes lineatus* (natural size).
4. Pupa (natural size).

mustard, which wire-worms loathe, and therefore they starve to death. In nurseries the beetles may be trapped in small heaps of lucerne, clover, or sainfoin laid on the ground and covered with tiles or pieces of board during May and June, as long as beetles are noticeable. They fly to these heaps, shelter beneath the green material (particularly if the ground is clean), and lay eggs there. These traps must be examined as often as possible, to collect the beetles, while the green stuff should be destroyed every ten days, and the ground beneath well beaten down to squash any eggs left there. Boards or tiles placed beneath the bait prevent eggs

from reaching the ground. The larvæ can also be trapped in beetroot or potatoes. Leaf-mould and manure-heaps should be dressed with gaslime to prevent egg-laying.

II. MOTHS (*Lepidoptera*).

A. SPINNERS (*Bombycidae*).

* **The Puss moth**, *Cerura vinula*, is often very destructive to young softwoods, especially Poplars. *Moth* about 1 in. long, greyish, soft, and fluffy (hence "puss"), fore-wings grey-white, with black markings, and partly transparent near edges; flies from April to June, and lays brownish eggs singly or in 2 or 3 on leaves of young Poplar and Willow chiefly. *Caterpillar* over 2 in. long, smooth, brownish above, with white strip along each side, and greenish-yellow at sides, has a black head, a hump

on the fourth segment, and a long forked tail. *Pupa* enclosed in a hard shell-like cocoon spun along the stem or on twigs, &c.

* **The Hop-Dog or Pale Tussock moth**, *Dasychira pudibunda*, is found on most broad-leaved trees, but mainly attacks old Beech-woods on poor soil (also destructive in hop-gardens, hence "hop-dog"), and usually only migrates to younger woods after the old woods have been defoliated. The caterpillars feed mostly in late summer, after the young buds for next year's foliage are formed; and though generation is simple and annual, attacks seldom extend beyond two consecutive years.

The wing-span of the ♀ 2 to 2½ in., the ♂ somewhat smaller and distinguished by yellowish-brown feathery antennæ; fore-wings and front part of body reddish- or greyish-white, with two or three dark, waved, transverse stripes; hind-wings and lower part lighter, with a faint, broad, greyish, transverse band. *Caterpillar* 16-legged, about 1½ in. long when full grown; at first greenish-yellow, then brown-red, and easily known by 4 thick, yellow- or brown-grey tufts of bristles on segments 4, 5, 6, and 7, with velvety black bands between, and by a long rose-red or ruddy-brown hair-tuft on the second last segment.

Pupa hairy, dark-brown to greyish-yellow, in a cocoon spun with the larval hairs. Moths fly late in May and early in June, and the ♀ lays about 100 eggs (at first grey-green, brown- or blue-grey) on the smooth bark of poles or trees, usually from 3 to 10 feet above ground. About three weeks later, in June or July, the young caterpillars hatch out, eat their egg-shells, and cluster in colonies for a few days before scattering and ascending to feed on the foliage. They only gnaw leaves slightly at first, but with growing strength often gnaw them completely through near the petiole, so that the ground is frequently strewn with bits of foliage. At end of September or early in October they descend and hibernate as pupæ in cocoons spun in moss or under dead leaves, herbage, &c. *Prevention and Extermination*.—Insectivorous birds and predatory and parasitic insects (*Carabidæ* and *Ichneumonidæ* chiefly) prey on the caterpillars; but the sudden cessation of attacks is mainly due to a fungus disease (*Isaria farinosa*) infecting the caterpillars, which are also very sensitive to sudden cold wet weather, although hardy as regards winter cold. It is not of much practical use to try and collect the pupæ or kill the caterpillars when descending to pupate on the ground, though egg-clusters laid on Beech-stems near the ground can easily be crushed or destroyed with a daub of tar. Grease-banding stems about 12 feet up with narrow rings of patent tar will prevent most of the caterpillars from getting up to the crown to eat the foliage, and will also hinder those hatched out of eggs laid above that from being able to descend to pupate on the ground.

The Brown-tail moth, *Porthesia chrysorrhæa*, is a shining white moth with a wing-span of 1½ in. In the ♀ the abdomen is mostly brown, with

a thick red-brown woolly tuft near the end, while the ♂ is blackish-brown with a red-brown woolly tuft at the end. The 16-footed *caterpillar* is $1\frac{1}{2}$ in. long, dark grey-brown above, with two irregular red stripes along the sides, and covered with tufts of yellowish-brown hairs, and grey beneath, with yellow marbling. The hairy *pupa* is dark-brown, and has a pointed tail. The moths fly late in June and early in July, the ♀ laying 200 to 300 brownish-yellow eggs, on the lower surface of the leaves of Oak chiefly, but also other broad-leaved trees, and covering them with spongy wool from her thick tail. The caterpillars hatch out in August, and form "tents" or colony-nests round the young shoots and leaves, and in autumn they strengthen these and form tough nests about fist-size, where they hibernate. In spring they again feed on the foliage, returning to their "tents" at night and during bad weather; but about the middle of May they abandon these and wander about freely to feed. Early in June they pupate for 3 to 4 weeks in a greyish-brown transparent nest made between the leaves. (Generation simple, annual).—The **Lackey moth**, *Gastropacha neustria*, has a wing-span of $1\frac{1}{4}$ in.; body and forewings yellow- or reddish-brown, with a broad, light-edged transverse band; hind-wings are somewhat lighter, and crossed in the middle by a faint darker band. *Caterpillar* is slightly haired, $1\frac{3}{4}$ in. when full-grown, and marked with alternate stripes of light blue, reddish-brown, and white (hence "lackey"), head pale-blue with two black spots. The moths fly in July and August, towards evening, and lay 300 to 400 brownish-grey eggs in a close spiral band round twigs and small branches, chiefly on Oak, also Elm, Hornbeam, Poplars, and Willows. The caterpillars hatch out late in April or early in May, at once feed on buds and leaves, and live in communities inside "tents" or nests until full-grown. About end of June they break up their colonies, and pupate singly between leaves or in bark-fissures, by attaching themselves to these with a few loosely spun threads. — The **Black Arches** or **Nun moth**, *Liparis monacha*, one of the most destructive pests in Continental Spruce and Pine woods, has never yet done much damage in Britain, though often found on broad-leaved trees (especially Oak) in the south of England.

The ♀ has a wing-span of about 2 in.; the smaller ♂ is distinguishable by double-combed antennæ. In both the outer wings and the upper part of the body the ground-colour is white, marked with numerous deeply-arched, zigzag, brownish-black or black stripes (hence Nun); the lower wings are brown-grey, edged with black spots. The abdomen, though sometimes blackish, is mostly rose-colour, with black transverse bands. *Caterpillar* about $1\frac{1}{2}$ in. when full-grown, whitish- to reddish-grey above and dirty-green below, with broad grey dorsal stripe, commencing from a black heart-shaped patch on the second segment. The densely-haired *pupa*, at first greenish, then bronzy-brown, lies in a flimsy cocoon, formed

of a few dirty yellow threads spun between bark-fissures on the lower part of the stem, among foliage on branches and twigs, or on underwood and brushwood. The moths fly late in July or early in August, and the ♀ lays about 150 bronzy mother-of-pearl eggs in one or more clusters under bark-scales, lichen, &c. Though fully formed in 4 weeks, the larva hibernates within the shell, and hatches out in April or May, the young caterpillars remaining for several days in clusters, then scattering and ascending to feed on the foliage. Spruce foliage they devour entirely, but on Pine they bite through the needle about half-way up, and eat only the remaining lower part. The caterpillars moult 4 times, and until half-grown spin gossamer threads to let themselves down to the ground. They feed till late June or early July, when they descend in masses from the stems to pupate under bark-scales, or on the undergrowth, &c. The most efficient exterminative measure is therefore grease-banding stems with patent tar (Fig. 36, p. 189).

The Satin moth, *Liparis salicis*, has a wing-span of $2\frac{1}{4}$ in., white lustrous wings, and legs ringed black and white. *Caterpillar* $1\frac{3}{4}$ in., grey, with yellow-white dorsal spots, small red warts, and light-brown hairs. The ♀ lays about 150 eggs in June and July on bark or leaves of Poplar and Willow, and covers them with a white skin. Some caterpillars hatch out in autumn, others in spring; and they pupate in May or June loosely attached to twigs or leaves.—**Vapourer moth**, *Orgyia antiqua*, wing-span 1 to $1\frac{1}{4}$ in.; ♂ rusty-brown, with 2 dark transverse bands and a white moon-spot on each fore-wing; ♀ yellowish-grey, with wings aborted into white stumps. *Caterpillar* ashy-grey with yellowish hairs, velvety-black head and carmine warts, with 2 long black hair-tufts behind its head, and other 2 on fifth segment projecting at right angles from sides, and 1 erect on eleventh segment. Moth flies in August and September, and lays about 200 eggs on the nest from which it has emerged. Some larvae hatch out in autumn, but most in spring, when they feed on the buds and foliage of Willow, Spruce, and Pine before pupating in June or July for about 6 weeks.

B. OWLET- or NIGHT-MOTHS (*Noctuidæ*).

* **The Pine Beauty or Owlet-moth**, *Trachea piniperda*, lives mostly in Pine-woods 20 to 40 years old, and in warm dry weather may become a very serious pest.

The ♂ and ♀ *moths* are about same size (wing-span $1\frac{3}{4}$ in.) and similarly marked; but antennæ of ♂ more feathered, and abdomen of ♀ rather thicker; fore-wings and upper part of body brown-red spotted with white or marbled with grey, and the large lower spot on each wing forms a crescent pointing downwards when moth is at rest; the hind-wings and abdomen dark-grey brown, wings with lighter edge. *Caterpillar* 16-legged, $1\frac{1}{2}$ in. long, with a brown head, has very few hairs, and is yellowish-green,

with 3 to 5 whitish longitudinal stripes, and a yellow or orange stripe on each side just above the spiracles and the legs. The two first abdominal legs being malformed, it moves somewhat like a span-worm, and spins gossamer threads freely while young. *Pupa* $\frac{1}{2}$ to $\frac{2}{3}$ in. long, first greenish, then dark-brown, with two hooked processes at tail-end. *Life-history*.—The moth flies in April, pairing at night, and laying, high up in the trees, about 50 round green eggs, mostly singly, on the needles of Pine and Spruce in pole-woods 20 to 40 years old. Caterpillars hatch out in May, and gnaw the sides of needles, but as they grow stronger, they eat them right down to the sheath. About the end of July they descend to pupate under moss, dead foliage, &c., or on the ground, throughout the whole area attacked, though they are not migratory.

They hibernate as pupæ and emerge as moths in spring, the long pupal rest extending over about eight months. *Prevention and Extirpation*.—In young pole-woods infested, caterpillars can easily be shaken down; and they can also often be collected and killed when they come down to pupate, as they frequently cluster together at the foot of the tree before hibernating as pupæ.

C. SPAN-WORM MOTHS (*Geometridæ*).

* *The Winter moth*, *Cheimatobia brumata* (Fig. 50), attacks most broad-leaved trees, but especially Oak, Elm, Hornbeam, and Lime.

The ♂ has a wing-span of 1 to $1\frac{1}{4}$ in., reddish- or yellowish-grey or grey-brown fore-wings with dark wavy transverse lines, and lighter hind-wings marked with a faint dark stripe; ♀ about $\frac{1}{3}$ in. long, grey-brown with white scales, long

antennæ and legs, and only abortive rudimentary wings, so that it cannot fly. The 10-footed *caterpillar* feeds on foliage till full-grown. Grey at first, after first moult yellowish-green with green head and pale dorsal stripe, and when full-grown (1 in. long) is green with dark dorsal stripe, three narrow white lines along each side, and brown head. *Pupa* light-brown, with two hook-like processes at tail-end in a very loose flimsy cocoon.

From October till December (hence "winter-moth") ♂ flits about towards dusk in search of ♀, crawling up and down the trunks of trees, and the ♀ lays about 250 eggs (greenish at first, then reddish), singly or in small clusters, on buds, leaf-scars, and twig-points in the crowns of broad-leaved trees. Caterpillars hatch out in April and May, and feed on leaf- and flowering-buds before attacking the foliage, which they twist

Fig. 50.

Winter Moth (natural size).

A. Male. B. Female.
C. Caterpillar.

(like leaf-roller moths). Early in June they spin gossamer threads down to the ground, and pupate in sheltered places or in smooth holes formed about $2\frac{1}{2}$ in. below the ground. The moths mostly emerge in autumn (simple annual generation), though stragglers hibernate as pupæ and appear in spring. *Extermination* consists in spraying with insecticides in nurseries, and grease-banding stems with patent tar to prevent the ♀ from crawling up to the tree-crowns.

Fig. 51.

* The Pine Span-worm or Bordered White moth, *Fidonia pinaria*, usually attacks 25- to 40-year-old Pine, Spruce, and Silver Fir woods, and would be very destructive were it not that its attacks only take place after the buds for next year's foliage have been formed (Fig. 51).

The ♂ and ♀ are about same size, wing-span 1 to $1\frac{1}{2}$ in., but vary in colour. The ♀ has rusty-brown wings (both pairs), with paler edging, 2 faint dark-brown transverse stripes across lower, and 1 across the upper wings, and the lower edges of both wing-pairs have a row of

Part of Pine branch, showing damage done by caterpillars of the Pine Span-worm. Eggs can be seen here and there on the leaves.

alternate light and dark spots. Ground-colour of wings of ♂ white (Scotland) or yellowish-white (England), with large triangular dark-brown patch at apex of fore-wings, and broad dark-brown edging and transverse stripes, and fringes of both wing-pairs tipped with alternate brown and yellow spots.

The yellowish-green 10-footed caterpillar, 1 or $1\frac{1}{4}$ in. when full-grown, has a white line along the middle of back, two parallel dark-green lines

farther down on either side, and a pale-yellow line close below the brown spiracles; and all these lines extend to the green head, where the dorsal middle line forms a V mark. Of the 10 feet, 3 pairs are thoracic, and 2 pairs prolegs (one pair forming the anal claspers).

Fig. 52.

Oak Leaf-roller Moth—natural size.

- a. Moth.
- b. Caterpillar spinning down.
- c. Oak-leaf rolled up for pupation.
- d. Pupa.

The *pupa*, about $\frac{3}{8}$ in., resembling but smaller than that of the Pine Beauty, is at first greenish, then dark-brown. The moths live for about a fortnight in May and June, when the δ flits about in the daytime, and the f lays about 60 bright-green eggs on Pine-needles near the top of poles and at tips of side-shoots. Caterpillars hatch out in 2 to 3 weeks, and gnaw the needles slightly, then bite them through about the middle so that the upper half falls to the ground, and feed on the remaining half. Before pupating in October under moss, leaves, &c., they spin down to the ground. Pupation lasts till April, the pupæ lying unprotected by a cocoon, and scattered over all the area infested. *Extermination* is by spraying with insecticides, shaking and tapping poles, and collecting caterpillars in summer, and by raking and burning the dead foliage in autumn; swine and hens also useful.

The Mottled Umber moth, *Hybernia defoliaria*, appears in October; f wingless, black-mottled; δ wing-span $1\frac{1}{2}$ in., fore-wings light-brown, paler near middle, and with a broad, dark-brown, pale-edged, irregular transverse band, hind-wings paler and with dark central spot or black-mottled. *Caterpillar* reddish-brown above, sulphury-yellow at sides, with dark or black strip between. Habits much like those of *Cheimatobia*

brumata, but chiefly attacking Oak, Sycamore, and Hornbeam.

D. LEAF-ROLLER AND TWIG-TWISTER MOTHS (*Tortricidæ*).

* **The Green Oak Leaf-roller**, *Tortrix viridana* (Fig. 52), often defoliates middle-aged and old Oaks entirely (and particularly the pedunculate

Oak, the Sessile Oak being comparatively immune), then attacks other broad-leaved trees. Every few years it swarms in great numbers over extensive areas, entirely devouring the pedunculate Oak foliage, checking the growth of the tree, and preventing the ripening of acorns. The eggs being laid on buds and young twigs, caterpillars always begin to feed near the top and move downwards, totally defoliating the tree; but the foliage is to some extent replaced by the summer flush.

Wing-span under 1 in., fore-wings pale bright-green, with a whitish or yellowish fringe round lower edges, hind-wings light-grey edged with white-grey. *Caterpillar* about $\frac{1}{2}$ in. long, 16-legged (10 prolegs), at first grey-green, then dark yellowish-green, with black head and small black tubercular warts with a few fine hairs on the back. *Pupa* blackish-brown, slender, under $\frac{1}{2}$ in. long. Moths fly in June, and ♀ lays eggs singly or in small clusters on buds then being formed in the crowns of Oak-trees. The caterpillars hatch out when the Oak-leaves flush in the following May, eat the leaves, and then spin down to the lower foliage, and in June pupate in remnants of leaves rolled together (hence "leaf-roller"), bark-fissures, &c. About three weeks later the moths emerge, pair, and lay their eggs (generation simple and annual). As this insect spends all its life on the tree, and the ♀ can fly to lay eggs far and wide, birds form the best check, and should be encouraged to breed in nesting-boxes. When late frosts nip the young Oak foliage during years when the caterpillars abound, these are starved to death.

* **The Pine Shoot-twister**, *Retinia buoliana*, mainly attacks Pines of from 5 to 12 years old growing on poor soil with a warm exposure.

Wing-span under 1 in.; fore-wings narrow, reddish-yellow, with six or seven broad, wavy, silvery-white, transverse bands, tinged bluish about middle, and with grey-white edging, hind-wings glossy dark-grey, and both pairs with light-grey fringe. *Caterpillar* 16-legged (10 prolegs), $\frac{1}{2}$ in. long, light-brown, with glossy black head and thorax. *Pupa*, dirty yellowish-brown, $\frac{1}{2}$ in. long, with a row of fine dorsal prickles. The moth flies in the evening during July, and in daytime rests among needles and shoots of young Pines. The ♀ lays eggs singly on terminal buds of young Pine shoots of 5- to 12-year-old plantations. Caterpillars hatch out in August and begin to bore, but the damage is hardly noticeable. In September they hibernate in the buds, and in spring the caterpillar, now larger, does greater damage; but the bud develops partially before the shoot, hollowed out, dies. The terminal bud is hollowed out first, and then the side-buds; but if one of these escape it becomes the leading-shoot, the bend at the damaged place being still recognisable when the tree is mature. Pupation takes place in June at the base of the hollow tunnelled in the shoot, and moths emerge about four weeks later. *Prevention and Extermination*.—To destroy the caterpillars and pupæ,

break off and burn from May till the middle of June all shoots infested. Shoots attacked are easily seen, but the insect must be looked for below where the twig breaks.

The Pine-bud Tortrix, *Retinia turionana*, attacks Pine plantations of 5

Fig. 53.

The Larch Mining-Moth
(all magnified three times).

- a. Moth.
- b. Larval covering formed of leaf-case.
- c. Caterpillar.
- d. Pupa.

- a. Larvæ in leaf-cases.
- b. Naked larvæ.
- c. Needles hollowed out.

to 15 years old, but seldom occurs in large numbers, and as not often all the side-buds forming the whorl are injured, one of these generally becomes a leading-shoot. It is smaller than *Tortrix buoliana*; as also is the **Pine Resin-gall Tortrix, *Retinia resinella*,** common in Scotland, which bores into shoots below the whorl of buds, and lives inside a gall formed by resin outflow. Branches become twisted, and break off easily.

E. LEAF-MINING MOTHS (*Tineidæ*).

* **The Larch Mining-moth**, *Coleophora laricella* (Fig. 53), besides doing great damage by defoliating young Larchwoods, opens entrance-holes for the canker-fungus. Moth wing-span under $\frac{1}{2}$ in., wings ashy-grey or grey-black, with long silky fringes on lower edges. *Caterpillar* with 16 feet (10 prolegs), dark ruddy-brown, $\frac{1}{8}$ in. long. *Pupa* $\frac{1}{8}$ in. long, dark-brown, narrow, covered with fine bristly hairs. Moths fly in May and June, and lay round yellow eggs (soon turning grey) singly on Larch leaves in plantations 10 to 40 years old, and mostly on lower branches of 10- to 15-year-old poles. The caterpillars hatch out in 3 to 4 weeks, bore into the leaf, eat its contents, and use the empty leaf-case as a protective covering. When full-grown in September it hibernates in this empty leaf-case (now a little yellow-brown sack) attached to twigs, bark-fissures, &c. Next spring it feeds on the new leaves, carrying its sack, and finally pupates in it. Leaves attacked at once wither as if frost-bitten, whole plantations sometimes looking as if badly nipped by late frost. *Extermination*.—Small birds, ichneumonidæ, &c., prey on caterpillars, and late frosts and heavy rainfall kill many moths; but the only practicable measures are to thin Larch-woods in winter or early spring, and remove the thinnings before moths appear in May.

* **Larch Shoot-boring moth**, *Argyresthia levigatella*, has recently done serious damage to young Larch plantations up to 20 years old. Wing-span under $\frac{1}{2}$ in.; fore-wings glossy silvery grey, with grey or brown-grey fringes, hind-wings dark-grey, not so glossy, abdomen dark-grey. *Caterpillar* pale-yellow at first, then pale-grey with reddish tinge, and dark-striped near end of back, about $\frac{1}{4}$ in. long, head and 3 front leg-pairs black. *Pupa* dark-brown, head black, pointed towards end. Moths appear in May and June, lay eggs on lower part of new shoot, that hatch out and bore into the shoot, where they feed till hibernating in autumn. Early in spring they resume feeding till about end of April, then pupate in the now half-dead shoot, and emerge as moths about four weeks later. *Extermination* by cutting off and burning damaged shoots containing the caterpillar or pupa.

F. WOOD-BORING MOTHS (*Cossidæ*).

* **The Goat-moth** or "Augur-worm," *Cossus ligniperda* (Fig. 54), does great damage to broad-leaved trees by the caterpillars boring through the bark into the timber, and often killing old Oak, Elm, Willow, and Poplar. Badly-bored trees are often thrown during storms; and unless exterminative measures are adopted, trees attacked become breeding-places.

Wing-span $2\frac{1}{2}$ to 3 in. for ♀ and 3 to $3\frac{1}{2}$ for ♂; fore-wings grey-brown, mottled with ashy-grey, and with numerous irregular dark-brown streaks and marks; hind-wings ashy-grey to grey-brown; thorax densely haired, with blackish band across it behind, and brown and grey in front. Ab-

domen large and blunt, with dusky-brown and grey bands. *Caterpillar* 16-footed, 3 to 3½ in. when full grown, at first reddish-yellow, then brownish-

Fig. 54.

Goat-Moth—natural size.

a. The female moth. b. Caterpillar. c. Pupa. d. Cocoon, after moth has emerged.

red, with brown head and shield, darker above than below, naked, and having goat-like smell (hence "goat-moth"). *Pupa* thick, ruddy-brown with rings of prickles on the abdominal segments.

Moths appear in June and July, when the ♀ lays about 25 eggs, in bark-

crevices of tree-stems. Caterpillars hatch out in July, and at first feed under the bark, but soon bore into the wood, forming long tunnels in which they live for from 2 to 4 years, sometimes leaving the trees and crawling about on the ground. When mature they usually pupate just inside the entrance to their borings (or sometimes in the ground), the large reddish-brown pupa lying in a cocoon of rough wood-chips. Previous to the moth emerging in June or July, the pupa pushes its way partly out of the tree (life-cycle 2 to 4 years).

Little can be done to prevent attacks, but pouring in carbon bisulphide and then plugging up the holes should kill the caterpillars. Badly infested trees should be felled, and the caterpillars destroyed; and the lower parts of tree-trunks attacked may be smeared early in June with a thick dressing of mud and paraffin to prevent egg-laying.

* **The Wood Leopard-moth**, *Zeuzera aesculi*, does damage like the Goat-moth, and attacks young Maple, Sycamore, Ash, and Lime far more than Horse-chestnut (though named after it).

Only about $\frac{2}{3}$ of the size of the Goat-moth; wings white, with numerous irregular round black or steel-blue spots and six similar spots in two rows on upper part of body; abdomen dull white or grey, striped alternately with blue-black and white bands; *caterpillar* yellowish, with little black warts, nearly 2 in. long when full-grown; *pupa* bright brown, about 1 in., with rows of sharp spikes along its back. Moths fly in June and July, and lay oval orange eggs on stems and branches of trees; and in a few days caterpillars hatch out, bore into the bark, feed in the sapwood till winter, then bore deeper, tunnelling upwards, and feed continuously till May or June of the second year, when they return to near the bark, pupate in the sapwood, and emerge as moths in June or July, the empty cocoon being left sticking out from the exit hole (generation biennial). *Extirpation* as for Goat-moth.

G. CLEARWING-MOTHS (*Sesiidae*).

The Hornet Clearwing-moth, *Sesia apiformis*, damages the butts of young Poplar up to about 20 years old in much the same way as the Poplar Longhorn and the Goat-moth.

Wing-span $1\frac{1}{2}$ to $1\frac{3}{4}$ in., wings transparent, with rust-red edges and veins. *Caterpillar* with 16 feet (3 pairs true legs, and 5 pairs suckers or prolegs), rather flat, dirty yellow-white, with large ruddy-brown head, and dark dorsal line; its head and legs distinguish it from the Poplar Longhorn larva, along with which it often attacks. *Pupa* brown, with prickly dorsal spines on abdomen and at tail-end. Moths fly in June and July, and lay brown eggs in bark-fissures near foot of Poplar stems. Caterpillars hatch out in July and August, bore into stem, live there for two winters, then come out and pupate near the mouth of the bore-hole or on or near the ground in cocoons formed of bore-dust (generation two years). *Extirpation* by killing the moths on the Poplar stems (June, July); cutting

and removing infested poles ; smearing butts of young Poplars with patent tar or cart-grease where the pest is known to be.

Fig. 55.

Pine Sawfly.

a. Male (twice magnified).

b. Female (twice magnified).

Caterpillars at work ; on right a cocoon
(natural size).

Damaged twig of Scots Pine.

III. MEMBRANE-WINGED INSECTS (*Hymenoptera*).

A. SAWFLIES (*Tenthredinidae*).

* The Pine Sawfly, *Lophyrus pini* (Fig. 55), chiefly attacks Scots and Austrian Pine, the caterpillars devouring the leaves till the tree is de-

foliated, and attacks lasting from May to September (second brood). Their power of reproduction is wonderful; and but for useful insects and fungus diseases checking them, they would soon destroy extensive woods. They mostly attack young plantations, and often confine themselves to one spot at a time.

Wing-span of ♀ about $\frac{4}{5}$ in., antennæ short and bristly, with 18 to 30 joints, head black, body yellowish with black spots on thorax and abdomen, and three black rings on abdomen; wing-span of ♂ $\frac{3}{5}$ in., body black, legs yellowish, antennæ combed or double-feathered. The light yellowish-green tailed *caterpillars*, 1 in. long, have 22 legs, a light-brown head, and 2 black dots at every proleg, and when touched, raise their heads. *Pupa* is enclosed in a tough, oval, brown cocoon in bark fissures, on twigs and needles, or under moss and dead foliage on the ground. Cocoon opens by a circular lid, unless attacked by ichneumon-flies, when its top is marked thus ⊙.

In dry warm seasons there may be two broods. The sawflies appear mostly in May, and lay about 120 eggs on the edges of Pine-needles, after scratching them with a saw-like egg-layer (hence "sawfly"), about 15 being laid in one needle and each wound sealed up with frothy slime. Caterpillars hatch out in about a fortnight, collect in clusters on the whorls of young Pine in sunny places or on suppressed stems, and at first usually feed in pairs on each needle, eating the edges and leaving the midrib standing; but when nearly full-grown they eat all the needle. Fortunately they only feed on old, and not on new leaves. They moult several times, leaving the cast skins sticking to twigs. In July they pupate in their peculiar leathery cocoons, and in 2 to 3 weeks the sawflies emerge, pair, and lay eggs for a second brood. This second brood hatches out in August, and feeds till autumn, then descends to hibernate (*as larvæ*) under moss or dead leaves, and only pupates in the following spring, about three weeks before emerging as sawflies. But even single broods may pupate for a year or longer before emerging as sawflies.

Extermination—Insectivorous birds should be provided with nesting-boxes. The caterpillars, when collected in clusters, may be crushed by pulling the gloved hand firmly along the twigs from below upwards, or using a C-spring *double brush*; or they may be shaken down if poles large enough; or if noticed early, spraying with insecticide is effective (such as hellebore-wash, 2½ lbs. to 10 gallons water, or arsenate of lead or Paris-green, 1 lb. to 150 gallons water); but these poisons require careful handling.

* **The Red Sawfly**, *Lophyrus rufus*, often attacks along with *L. pini*, and mostly Scots Pine 2 to 6 ft. high.

Flies in August and September: ♀ ruddy brown or yellow, with black spots on thorax; ♂ smaller, glossy black, with first abdominal ring and

feet (except claws) red or red-brown. *Caterpillars* dusky greenish-grey with black head, pale longitudinal stripe along back, and dusky line with a pale one on each side of it above and below, the spiracles being placed in the lower pale line; sucker, feet, and under side of body pale-green. When full-grown over $\frac{1}{2}$ in. long; has also habit of raising its head when disturbed. Larvæ hatch out about end of May, and feed for 3 to 4 weeks before pupating in an oval, pale yellow-brown parchment-like cocoon (paler, and not so tough as that of *L. pini*) among needles and heather or in the earth. It also collects in colonies, and two usually attack each needle. The sawflies emerge, pair, and lay eggs in August and September in the needles (in the same way as *L. pini*), which remain there all winter, and hatch out in May. *Extermination* as for Pine Sawfly.

* **The large Larch Sawfly**, *Nematus Erichsoni*, feeds on Larch foliage, and has since 1905 been spreading so quickly and doing so much damage that it is scheduled under the *Destructive Insects Act*, 1907, and must be reported to Board of Agriculture (penalty up to £10 if not reported). Larch of all ages are attacked, from plantations of 3 or 4 years old up to 70-year-old woods. Flies appear from middle of May till end of June.

Wing-span nearly 1 in.; ground colour, head, and thorax black; abdomen black, red, and black; thorax thickly and prominently punctured; antennæ 9-jointed, thick, tapering at end. *Caterpillar*, with 20 legs, $\frac{3}{4}$ to nearly 1 in. when full-grown, black head, grey-green on back, pea-green on sides, with brown spiracles. It feeds till end of August chiefly on the tufts of leaves on old shoots, and then hibernates in a dark-brown leathery cylindrical cocoon $\frac{3}{8}$ to $\frac{1}{2}$ in. long, with rounded ends, and pupates there. In May and June the sawflies issue and lay their white longish-oval eggs in one or two rows on the youngest shoots and in slits sawn in the bark. The caterpillars hatch out in June and July, and attack the foliage till they descend to hibernate in cocoons formed below moss litter, &c., before turning to pupæ in spring (generation annual, so far as yet observed). *Extermination* as for *L. pini*.

* **The small Larch Sawfly**, *N. laricis*, is smaller and quite black, and thorax smooth or not prominently punctured. *Caterpillar*, hatching out from eggs laid on buds, $\frac{3}{8}$ in. long, head brown, body grass-green or greenish-brown, full grown in July, and mostly eating the single leaves on the new shoots.

B. WOOD-WASPS (*Siricidæ*), the largest of our *Hymenoptera*, bore deeply into Conifers and softwoods with a long, strong egg-layer, and (though only living for a week) lay about 120 eggs singly in sound stems. The roundish white grub, about 1 in. long when full-grown, has 3 pairs of small thoracic feet, strong jaws, and a characteristic spine on last segment. It bores first in the sapwood, then goes deeper and hibernates; in second year it bores still deeper, and again hibernates; and in following

spring it ascends and pupates in the sapwood, and between July and September emerges from a straight round hole (generation 2 years or more).

The Large Yellow Wood-wasp, *Sirex gigas*, mostly attacking Spruce, Silver Fir, and Larch, is blackish, with a yellow patch behind each eye; and in the ♀, $1\frac{1}{2}$ in. long, the first 2 and the last 3 segments of the abdomen are yellow; while in the smaller ♂ all are reddish-yellow, except the first and the last, which are black.—**The Steel-blue Wood-wasp, *Sirex juvencus***, bores chiefly in Pine and Larch. The ♀, $1\frac{1}{2}$ in. long, has a steel-blue body with reddish legs, while the ♂ is smaller and has yellowish-red rings from the fourth to the seventh abdominal segments. *Extermination* consists merely in cutting out sickly or damaged stems and thinning the woods properly.

C. GALL-WASPS (*Cynipidæ*) have fore-wings with 6 or 8 bays, 1 long at apex and 2 or 3 rhomboidal at edge, but sometimes only aborted wings, or none at all; ♂ usually much smaller than ♀. *Larvæ* generally thick, fleshy, smooth, whitish, and incurved. *Pupæ* thick, smooth, and whitish. Many species have an intermediate sexless form, also laying eggs, which hatch out insects differing in appearance and habits from those issuing from sexually fertilised eggs. The commonest kinds are the **Oak-apple Gall-wasp, *Cynips quercus***, forming red and green galls about cherry-size on the lower side of oak-leaves, and the **Marble Gall-wasp, *C. Kollari***, on young oaks in nurseries.

IV. TWO-WINGED INSECTS (*Diptera*).

The injurious insects of this order are the gall-gnats (*Cecidomyidæ*), the chief being the **Large Osier gall-midge *Cecidomyia salicis***, $\frac{1}{4}$ in. long, blackish, long-legged, with red-ringed, whitish-haired abdomen, which lays eggs on osier-shoots in May and July, hatching out into reddish-yellow maggots that spoil the rods by causing spindle-shaped nodes, in which pupation takes place; the **Small Osier gall-midge, *C. saliciperda***, $\frac{1}{16}$ in. long, with black-brown body and white wings, appearing in May, and doing similar damage; and the **Osier shoot-tip gall-midge, *C. heterobia***, forming galls on the terminal shoots. *Extermination*, cutting off and burning infested twigs.

V. HALF-WINGED INSECTS (*Hemiptera*).

The class *Homoptera*, having fore- and hind-wings alike, includes the often very destructive Plant-lice and Scale-insects, which rapidly multiply enormously without any distinctly marked metamorphosis, the larvæ moulting several times and the wings being freed at the last moult.

Among the **Plant-lice (*Aphidæ*)**, by far the most injurious is * the

Spruce-gall and Larch aphid, *Chermes abietis-laricis* (Figs. 56, 57), a small louse pricking into or just below the side-buds of Spruce and forming small green cone-like galls at the foot of the twig developing from such bud, in which colonies of the lice live, and which turn brown and dry when the lice (all ♀) make their exit, some remaining on the Spruce and forming similar galls in the second year, and others flying to and becoming white woolly lice on Larch (as *Ch. laricis*) and probably also those

Fig. 56.

Cone-like gall of Spruce Aphid.

Fig. 57.

a. The Larch Aphid sucking sap from the leaves, which get bent.

found on Pine (as *Ch. pini*) and Silver Fir (as *Ch. piceæ*). On this intermediate host wingless ♀ lice are in the following year produced, which lay eggs hatching out winged adults that fly back to the Spruce and there produce a sexual brood (♂ and ♀), laying eggs upon side-buds and producing the cone-like galls again. Thus, while wingless ♀ lice remain always on the Spruce forming galls, there is every year a migration to and from the Larch, bringing the sexual form (♂ and ♀) back to the Spruce. Hence exterminative measures such as spraying must continue

for at least 2 or 3 years to have the slightest chance of success. Besides the direct damage done, an entrance is opened for spores of the canker-fungus on Larch and of *Septoria parasitica* on Spruce.

The form known as the * **Spruce-gall aphid**, *Chermes abietis*, is only about $\frac{1}{12}$ in. long, yellowish-green or light-brown, and (when present) white wings and whitish bloom. About 25 eggs laid on the edges of bud-scales hatch out, suck the sap, and form the small rough cone-like gall, green at first, then brown and dry when the wingless brood emerges in July or August. The intermediate form, the * **Larch aphid**, *Chermes laricis*, mostly attacks young trees in nurseries and plantations 10 to 20 years old, and from May onwards is noticeable from its fluffy white coating. Under $\frac{1}{12}$ in. long, purplish- or blackish-brown, and covered with white fluff, it inserts a long sucker into Larch-leaves and feeds on their sap, then lays about 45 eggs on the twigs, which on hatching out scatter and live on the leaf-sap, soon get covered with white woolly down, fly and lay eggs from July to August. *Extermination of Ch. abietis-laricis* can only be successful by simultaneous collection of the young green galls on Spruce and spraying of infested Larch (and other intermediate hosts, such as Pine or Silver Fir) with insecticide for at least 3 years continuously. The best spray for Larch aphid is to dissolve 3 lbs. soft soap in $\frac{1}{2}$ gallon boiling water, stirring well till soap all melted, then add 1 pint paraffin to the still boiling mixture, and churn the whole till well mixed; to this add 5 gallons of soft water, and stir thoroughly when spraying.

The **Red Spruce aphid**, *Ch. coccineus*, produces similar but smaller false cones on Common and Menzies Spruce, at tip of twigs. The **Elm-blister aphid**, *Schizoneura ulmi*, produces large, heavy, sticky galls on the tips of Elm-shoots and leaves, and the **Elm-gall aphid**, *Tetraneura ulmi*, small club-like galls on the upper side of Elm leaves.

Among the **Scale-insects** (*Coccidæ*), * the **Felted Beech-scale**, *Cryptococcus fagi*, a wingless, legless, lemon-yellow louse only $\frac{1}{25}$ in. long (of which the δ form is not yet known), which punctures the bark, sucks the sap, permits the entrance of the spores of the canker-fungus, *Nectria ditissima*, and often kills the tree, unless exterminated by scrubbing with caustic alkali washes, or by spraying with paraffin emulsion (as for Larch aphid). The **Felted Ash-scale**, *Apterococcus fraxini*, on young Ash-trees after a heavy thinning on light gravelly soil, and the **Felted Willow-scale**, *Chionaspis salicis*, on Willow and Ash, are also similarly destructive, unless exterminated.

GENERATION TABLE SHOWING APPROXIMATELY THE USUAL LIFE-CYCLE OF INSECTS SOMETIMES VERY DESTRUCTIVE IN BRITISH WOODLANDS. (See page 192.)

INSECT.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov. to March.	GENERATION.
I. BEETLES. <i>Scolytus destructor</i> , the Elm bark-beetle	pupa pupa ²	beetle egg	beetle egg larva	larva	larva pupa beetle ² egg ²	larva larva ²	pupa larva ²	pupa larva ²	Annual (sometimes Double ²)
<i>Hylesinus piniperda</i> , the Pine-beetle	beetle beetle ² egg larva	beetle beetle ² egg larva	larva pupa beetle	beetle egg ² larva ²	beetle larva ²	beetle larva ² pupa ² beetle ²	beetle beetle ²	beetle ² beetle ²	Annual (sometimes Double ²)
<i>H. minor</i> , the small Pine-beetle			somewhat similar	to <i>H. piniperda</i>					do.
<i>H. palliatus</i> , the crutch Pine-beetle	beetle ² egg larva	larva	larva pupa	pupa beetle egg ²	larva ²	larva ² pupa ²	pupa ² beetle ²	beetle ²	Double ² (sometimes only Annual)
<i>H. fraxini</i> , the Ash bark-beetle	beetle	beetle egg larva	larva	larva pupa	pupa beetle	beetle	beetle	beetle	Annual
<i>Bostrychus bidens</i> , the 2-toothed Pine bark-beetle	beetle ²	beetle ² egg	beetle ² egg larva	larva pupa beetle egg ²	pupa beetle egg ² larva ²	larva ² pupa ² beetle ²	beetle ²	beetle ²	Double ²

<i>B. acuminatus</i> , the acuminate Pine bark-beetle	beetle ² egg (beetle)	beetle ² egg larva beetle	pupa larva	pupa beetle egg ² larva	beetles egg larva pupa of the last brood, and old brood, may always be found	beetle egg ² larva ² pupa	larva ² pupa ² beetle ² pupa	pupa ² beetle ² beetle	beetle ² beetle)	Double ² (sometimes only Annual)
<i>Hyllobius abietis</i> , the large Pine-weevil	beetles larva (young)	beetles larva beetles	beetles larva pupa of the last brood, and old brood, may always be found	beetles egg larva pupa	beetles egg larva pupa beetle ¹ egg ¹	beetle egg larva pupa beetle ¹ egg ¹	beetles larva beetles of the previous	beetles larva beetles of the previous	beetles larva beetles of the previous	Annual (but beetle can live and pair for 2 years)
<i>Pissodes notatus</i> , the small banded Pine- weevil	beetle egg larva	beetle egg larva	beetle egg larva	beetle egg larva	beetle egg larva pupa beetle ¹ egg ¹	beetle egg larva pupa beetle ¹ egg ¹	beetle ¹ egg ¹ egg ¹	beetle ¹ egg ¹ egg ¹	beetle ¹ egg ¹ egg ¹	Annual (sometimes 3 in 2 years)
<i>Orchestes fagi</i> , the Beech leaf-mining weevil	beetle egg	egg larva pupa	larva pupa beetle	pupa beetle	beetle	beetle	beetle	beetle	beetle	Annual
<i>Strophosomus coryli</i> , the Hazel-weevil	beetle	beetle	beetle egg	larva pupa	beetle egg	beetle	beetle	beetle	beetle	Annual
<i>Melolontha vulgaris</i> , the Cockchafer	pupa	beetle egg beetle	beetle egg larva before pupating)	beetle egg larva pupa	(feeds as larva for 3 complete years pupa	larva for 3 complete years pupa	larva for 3 complete years pupa	larva for 3 complete years pupa	larva for 3 complete years pupa	Quadrennial (beetles appear every 4th year)
<i>Rhizotrogus solstitialis</i> , the Summer-chafer	somewhat similar	to <i>Melolontha vulgaris</i>	do.	do.	do.	do.	do.	do.	do.	do.
<i>Phyllonetha horticola</i> , the Garden-chafer	beetle egg beetle	beetle egg larva	(feeds as larva for nearly 2 years)	do.	do.	do.	do.	do.	do.	Biennial (beetles appear every 2nd year)
<i>Saperda populnea</i> , the small Poplar- longhorn	pupa	beetle egg beetle	beetle egg larva	(feeds as larva for nearly 2 years)	do.	do.	do.	do.	do.	Biennial (beetles appear every 2nd year)

GENERATION TABLE, ETC. (continued).

INSECT.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov. to March.	GENERATION.
<i>S. carcharias</i> , the large Poplar- longhorn		somewhat similar to <i>S. populea</i>							do.
<i>Aromia moschata</i> , the musk-scented willow-longhorn		do.							do.
<i>Phratora vitellinae</i> , the Willow beetle	beetle egg	beetle egg	larva	larva pupa	beetle egg ² larva ²	beetle pupa ² beetle ²	beetle beetle ²	beetle beetle ²	Annual (sometimes Double ²)
<i>Agriotes lineatus</i> , the wire-worm beetle	beetle ...	beetle ... nearly 4	beetle egg larva (years)	beetle egg larva pupa	(feeds as beetle)	larva for beetle	... nearly 3 beetle	... or for beetle	Triennial or Quadrennial (beetle appears every 3rd or every 4th year)
II. MOTHS.									
<i>Dasychira pudibunda</i> , the Beech or Pale Tussock moth	pupa	moth egg	moth egg larva	larva	larva	larva	pupa	pupa	Annual
<i>Orygia antiqua</i> , the Vapourer moth	larva	larva	larva pupa	pupa	moth egg	moth egg	egg (some)	egg larvæ)	Annual
<i>Cerura vinula</i> , the Puss moth	pupa	pupa moth egg	moth egg larva	moth egg larva	larva	larva	pupa	pupa	Annual

<i>the Pine Owllet-moth</i>	pupa moth	moth egg larva	moth egg larva	larva	larva	larva	larva	larva	pupa	pupa	Annual
<i>Cheimatobia brumata</i> , the Winter moth	egg larva	larva	larva pupa	pupa	pupa	pupa	pupa	pupa	moth (till Dec.) egg	moth (till Dec.) egg	Annual
<i>Hybernia defoliaria</i> , the Mottled Umber moth			somewhat similar	to <i>Ch. brumata</i>							do.
<i>Fidonia pinaria</i> , the Bordered White moth	pupa	pupa moth	moth egg	larva	larva	larva	larva	larva pupa	pupa	pupa	Annual
<i>Tortrix viridana</i> , the Oak leaf-roller moth	egg larva	larva	larva pupa moth	moth egg	egg	egg	egg	egg	egg	egg	Annual
<i>Retinia buoliana</i> , the Pine shoot-twisting moth	larva	larva pupa	pupa moth	moth egg	egg larva	larva	larva	larva	larva	larva	Annual
<i>Coleophora laricella</i> , the Larch leaf-mining moth	larva	larva pupa moth	moth egg	larva	larva	larva	larva	larva	larva	larva	Annual
<i>Argyresthia levigatella</i> , the Larch shoot-boring moth			somewhat similar	to <i>C. laricella</i>							do.
<i>Cossus ligniperda</i> , the Goat moth	nearly 3 years	pupa	moth egg moth	moth egg larva	(feeds as larva for	larva for	larva for	larva for	or for	or for	Biennial or Triennial (moths appear every 2 or every 3 years)
<i>Zeuzera asculi</i> , the Leopard moth	years)	pupa	moth egg moth	moth egg larva	moth egg larva	(feeds as larva for	larva for	larva for	or for	or for	Biennial (moths appear every two years)

GENERATION TABLE, ETC. (continued).

INSECT.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov. to March.	GENERATION.
III. SAWFLIES. <i>Lophyrus pini</i> , the Pine sawfly	pupa fly	fly egg larva	larva	larva pupa fly	fly egg ² larva ²	larva ² (sometimes only the pupa)	larva ² pupa ²	pupa ²	Double ² (sometimes only Annual)
<i>L. rufus</i> , the small Pine sawfly	egg	egg larva	larva	pupa	fly egg	fly egg	egg	egg	Annual
<i>Nematus Erichsoni</i> , the Larch sawfly	larva pupa	pupa fly egg	fly egg larva	larva	larva	larva	larva	larva	Annual
IV. PLANT-LICE AND SCALE-INSECTS. <i>Chermes abietis-laricis</i> , the Spruce-gall aphid	louse egg	louse egg nymph	nymph louse	nymph louse	nymph louse	louse	louse	louse	...
the Larch aphid	louse egg	nymph	nymph louse	louse egg nymph	louse egg nymph	louse	louse	louse	...
<i>Schizoneura ulmi</i> , the Elm leaf-gall aphid	egg nymph louse	egg nymph louse	egg nymph louse	egg nymph louse	egg nymph louse	louse egg	egg	egg	Manifold (several in 1 year)
<i>Cryptococcus fagi</i> , the felted Beech-scale			somewhat similar	at similar	to <i>Sch.</i>	<i>ulmi</i>			do.

CHAPTER III.

PROTECTION AGAINST WEEDS, EPIPHYTES, AND FUNGUS DISEASES.

WEEDS include not only grasses, bracken, brambles, and many other plants that spring up in large numbers wherever there is sufficient light and moisture—and the more luxuriantly the better the soil is,—but also Birch, Aspen, Willows, and other trees not desired among, or interfering with, the growth of the young timber-crops. The thicker the growth of weeds, the more they are likely to harbour mice and voles; and the stronger their growth, the more they are likely to outgrow and overshadow young plants, and to overlie and smother them in autumn. Hence the necessity for **weeding** in young plantations for the first two and often three years (see page 75), and for afterwards cutting out quick-growing softwoods or Conifers that have been planted as temporary **nurses** to protect more valuable but less hardy kinds of young trees against frost and drought. So long as the leading-shoots of the young trees forming the crop are above the weeds, no damage can result, and a soil-covering of heather, &c., may then be beneficial by giving protection against frost, scorching, wind, blackcock, and even rabbits if not numerous; and this is gradually killed as the young crop closes laterally and forms canopy. If the weeds can be beaten back so as to clear the lines of plants, this is best, especially in the case of brambles, which throw out strong

shoots and suckers when cut. But if young pole-woods are thinned to any unnecessary extent, the soil gets overrun with weeds, while the valuable *humus* and part of the plant-food in the soil are to a great extent wasted in the unprofitable production of weeds giving back only an inferior, and sometimes an injurious, kind of *humus* to the soil. And the same is the case when older woods are heavily thinned, or partially cleared and underplanted, or naturally regenerated—for both the underplanting and the natural regeneration are artificially arranged for in order to utilise the soil profitably and prevent it deteriorating through useless growth of the weeds that would otherwise at once spring up.

Sometimes it happens that old branching Oak, &c., should be cut out to allow of proper growth of young poles, and if a thinning cannot take place for some years, such trees can be girdled, and seasoned on the stump meanwhile, by cutting a deep ring round them into the heartwood. For softwoods having no true heartwood, the girdle must be cut much broader; but girdling is unsuitable for Conifers (on account of insects).

Epiphytes like *beard-mosses* and *lichens*, which clog the air-holes (lenticels) of the bark, should be scraped off, if practicable (which is not the case in woodlands in damp, misty localities); or ornamental trees can be washed with 1 lb. sulphate of iron dissolved in a gallon of water, or a mixture of 1 lb. caustic soda and 1 lb. pearl ashes each dissolved in 5 gallons water, and $\frac{3}{4}$ lb. soft soap added. *Ivy* should be cut near the ground and as high up as one can reach; while *honeysuckle*, *wild clematis*, *convolvulus*, and *wild hops* should be dug out by the roots.

Parasitic Plants such as *mistletoe* on Poplar and other softwoods chiefly, seldom on Oak, and never on Beech, Alder, Larch, or Spruce, can be exterminated by pruning off infected branches; and osier-rods attacked by *dodder* can be cut and

burned in June. But of far greater importance are the *parasitic diseases* caused by **Fungi**, lowly plants without chlorophyll, unable to assimilate carbon, and dependent for their nutriment either on dead organic matter (*saprophytic fungi*) or on living animal or vegetable organisms (*parasitic fungi*). But many saprophytic fungi in our woodlands become parasitic whenever their spores happen to germinate on any wound-surface, however small.

Parasitic Fungi obtain nourishment through a *mycelium* with branching filaments (*hyphæ*) produced from spores borne by the *mycelium*. This often assumes a complex form of bundles of strands (*rhizomorpha*) with branching root-like processes, or the *hyphæ* form tuber-like masses (*sclerotia*) whose spores may long lie dormant before finding favourable conditions for germinating. Spores are produced in *sporangia* on special branches (*sporophores*) of the *hyphæ*, and may be either *gonidia* (*conidia*) formed at the points of *hyphæ* growing erect, or *sporidia* on a promycelium formed by the germination of resting-spores (*ovisporos*) produced sexually by the union of two cells or energids.

In parasitic Fungi the *hyphæ* pierce the cells of their host and generate ferments enabling them to dissolve the cellulose and the cell-contents and use them for their own nourishment; and they may either be *autoxenos* and complete their generation on one host, or *metoxenos* and spend part of their life on a second host usually belonging to quite a different kind of plant from the first, and during this intermediate stage the fungus appears to belong to quite a different genus. Trees of all ages are most liable to fungus attack if sickly from any cause whatever, *e.g.*, unsuitable soil or situation, partial suppression, or damage of any sort; and many dangerous diseases (*e.g.*, *Peziza*, *Nectria*) can only effect an entrance when wounds caused by insects, hail, &c., give their spores a chance of germinating, while others (*e.g.*, *Fomes*, *Agaricus*, *Rosellinia*) spread from root to root by mycelial infection.

The following are the chief Fungus diseases in our woodlands, the more destructive kinds being marked thus * :—

Name of Fungus.	Trees.	Parts.
	Chiefly attacked.	
I. In Nurseries and Young Natural Regenerations.		
* <i>Phytophthora omnivora</i> , Beech-seedling fungus	Beech, Ash, Maples	stalks, leaves.
<i>Cercospora acerina</i> , Maple - seedling fungus	Maples	stalks, leaves.
* <i>Rosellinia quercina</i> , Oak - seedling fungus	Oak	roots, 1-3-yr.-old plants.
* <i>Lophodermium pinastri</i> , Leaf-shedding disease	Pine	leaves, 1-6-yr.-old plants.
* <i>Botrytis cinerea</i> (syn. <i>Sclerotinia Fuckeliana</i>), Grape-mould	Conifers	leaves, shoots.
<i>Rhizina undulata</i> , young Conifer root-fungus	Conifers	roots.
<i>Rhizoctonia violacea</i> , Heather root-fungus		
II. In Plantations and Woods.		
* <i>Lophodermium pinastri</i>	Conifers	(as above).
<i>L. macrosporum</i> , Spruce leaf-scurf	Spruce	leaves.
<i>L. nervisequium</i> , Silver Fir leaf-scurf	Silver Fir	branches, twigs.
<i>Sphaerella laricina</i> , Larch leaf-shedding fungus	Larch	leaves.
* <i>Peziza Willkommii</i> (syn. <i>Dasyscypha calycina</i>), Larch canker	Larch	stem, branches.
<i>P. resinaria</i> , Spruce canker	Spruce, Larch	"
<i>Phoma pithya</i> , Douglas Fir canker	Douglas Fir, Pine	"
<i>Ph. abietina</i> , Silver Fir twig-canker	Silver Fir	branches, twigs.
<i>Septoria parasitica</i> , Spruce-shoot fungus	Spruces	leading-shoots.
<i>Trichosphaeria parasitica</i> , Silver Fir needle-blight	Silver Fir	leaves.
* <i>Nectria ditissima</i> , Canker of broad-leaved trees	Beech, Ash, Oak	stem, branches.
<i>N. cinnabarina</i> , Coral-spot fungus	Horse-chestnut, Maples	branches.
<i>N. curcubitula</i> , Spruce-bark canker	Conifers	bark, cambium.
<i>Rhytisma acerinum</i> , Sycamore leaf-blotch	Maples	leaves.
<i>Melampsora</i> genus—		
<i>M. pinitorqua</i> + <i>Cæoma pinitorquum</i> , { Pine shoot-twisting fungus	Aspens	leaves.
<i>M. larici-tremulae</i> + <i>C. laricis</i> , Larch leaf-blisters	Pines (1-10 yr.)	shoots.
<i>M. larici-populina</i> + <i>C. laricis</i> , Larch leaf-blisters	Aspens + Larch	leaves.
	Black Poplars + Larch	"

Name of Fungus.	Trees.	Parts.
	Chiefly attacked.	
II. In Plantations and Woods—continued.		
<i>Melampsorella</i> genus—		
<i>M. cerastii</i> + <i>Æcidium elatinum</i> , Silver Fir canker and twig-cluster fungus	<i>Cerastium</i> , &c. + Silver Fir Birch + Larch	leaves. stem, branches.
<i>M. betulina</i> + <i>Æc. laricis</i> , Larch leaf-blister		leaves.
<i>Coleosporium</i> genus (syn. <i>Peridermium pini acicola</i>), Pine leaf-blister	Groundsel, Ragwort + Pine (3-10 yr. old)	leaves. "
* <i>Cronartium</i> genus (syn. <i>P. pini corticola</i>), Pine bark-blister	Ribes, &c. + Pines	leaves. bark and wood.
<i>Chrysomyxa abietis</i> , Spruce leaf-blister.	Spruce	leaves.
* <i>Trametes pini</i> , Pine stem-rot.	Conifers	stem.
* <i>Fomes annosus</i> (syn. <i>Trametes radiciperda</i>), Conifer Red-rot root-fungus	"	root and stem.
<i>F. igniarius</i> , White-rot stem-fungus	Oak, Willows	wound surfaces on stem or branches.
<i>F. fomentarius</i> , " "	Oak, Elm	
<i>Polyporus sulphureus</i> , Red-rot stem-fungus	Oak, Birch	"
<i>P. vaporarius</i> , Red-rot stem-fungus	Spruce, Silver Fir Beech	
* <i>Agaricus melleus</i> , Beech stump-tuft or common Agaric	Conifers	Saprophytic on stumps. Parasitic on roots.

I. Chief Fungus Diseases in Nurseries and young Natural Regenerations.

* **The Beech-seedling fungus**, *Phytophthora omnivora*, chiefly attacks Beech-seedlings, the stalks becoming brown, the roots black, and the cotyledons and primary leaves spotted with brown before they wither, die, and rot quickly during rainy weather. In about a week from the first signs of the disease its full effect is noticeable if May and June are wet, while in dry seasons it takes longer for seedlings to assume the characteristic scorched, blackened appearance. During warm, damp, spring weather it may do great damage in Beech natural regenerations, as well as in nurseries. Besides being wind-borne, the spores are conveyed on men's boots and clothing, and by animals of all kinds. Next to Beech, it chiefly attacks Ash, Maple, and Sycamore, but also all other seedlings when once epidemic, and whole Conifer seed-beds may be destroyed before the seedlings even appear above ground. Resting-spores may lie dormant for years till finding favourable conditions for germination, and

during wet weather spore-producers are formed in 3 or 4 days from first signs of infection. Hence infected seedlings should be removed and burned before the disease gets epidemic, and infected seed-beds should be used as transplant lines for next 2 or 3 years, and preferably for some other kind of tree than that already attacked.

Remedy.—To prevent the disease spreading the seed-beds should be watered with a solution of $4\frac{1}{2}$ lbs. bluestone (copper-vitriol) and 1 quart ammonia in 50 gallons water. Men working on infected beds should be told to wipe their boots before working in other parts of nursery.

Cercospora acerina causes a similar disease among Maple and Sycamore seedlings in wet seasons, the cotyledons, primary leaves, and stalks becoming spotted or blackened and withering, and conidia-bearers appearing, while the mycelium assumes a thread-like dormant form and resumes activity next spring.

* **The Oak-seedling Fungus, *Rosellinia quercina*,** attacks and kills the roots of 1- to 3-year-old Oak in nurseries during damp warm weather; but plants are attacked up to about 10 years old, the terminal leaves of infected plants gradually wilting and dying. Roots infected become covered with finely-woven mycelium, the bark turns brown, and small, round, black pustules appear, especially where the first side-roots branch off. From these pustules fine thread-like rhizomorphs, whitish then brown, spread from root to root (as in *Agaricus melleus*, see p. 251), while the mycelium sometimes also grows above ground and produces conidia which germinate. By means of these small black pustular fruits (*sclerotia*) the fungus outlives periods of summer drought, and when the air becomes damp again they develop a whitish-grey, mould-like mycelium producing brown rhizomorphs which enter the unprotected tips of rootlets.

Remedy.—In nurseries diseased plants should be removed and burned, and beds used for other plants: in young plantations or natural regenerations the infected area should be isolated by a trench about 1 ft. deep to prevent rhizomorphs spreading.

* **The Pine leaf-shedding disease, *Lophodermium pinastri*,** is caused by a saprophyte on dead Conifer foliage, that can become parasitic, and chiefly on young 1- to 6-year-old Pine and other evergreen Conifers, to which it is very destructive (damage on old plants being slight). Seedlings and transplants in nurseries are thereby rendered useless.

During late summer and autumn the needles become speckled with reddish-brown spots, containing the mycelium, and in the following March or April the leaves wither, turn red or brown, and die off, the dead 1-3-year-old leaves usually adhering to the young shoots, while the older needles generally fall off ("leaf-shedding"). If the winter has been mild, open, and followed by a wet spring, black fruits (*apothecia*) appear early, and burst and scatter their spores, but the disease is chiefly spread

by spores produced in black spore-cases during the second or third year. The development of *L. pinastri* depends greatly on a damp condition of the air ; and dry summers, cold winters, and dry spring weather check its spread, while a moist summer, followed by an open, mild winter, favour it.

Remedy.—Avoid use of Pine foliage in nurseries ; pull up and burn infected plants ; and spray annually in July and August or oftener with *Bordeaux mixture*, 2 lbs. sulphate of copper (bluestone, copper-vitriol) dissolved in 10 gallons water, and 1 lb. freshly-burned lime added, which generally, though not always, checks the disease.

* **The Grape-mould**, *Botrytis cinerea*, saprophytic on dead Conifer foliage, but also spreading as a destructive parasite on all Pines, Firs, and Larch in nurseries and natural regenerations, is the conidia-form of *Sclerotinia Fuckeliana*, and often does serious damage in wet springs and summers, especially to Douglas Fir, Silver Fir, and Spruce. If Conifer sprays or foliage be used in nurseries there is always great danger of this disease appearing first as a saprophyte, then becoming parasitic, when the shoots of young plants attacked become twisted or bent, and the leaves die off as if frosted, though often held together by the ashy-grey cobweb-like mycelium. Spores alighting on young leaves or shoots in damp weather soon germinate and enter the tissue, the mycelium penetrating intercellularly and killing the tissues. Sporophores and sclerotia are formed, the spores remaining dormant and germinating with favourable conditions. On germinating, the spore-tubes cannot pierce the bark of a 2-year-old seedling, except at a wound-surface caused by late frost, insects, &c., when the fungus destroys the cambium and kills the plant.

Remedy.—Spray frequently with *Violet Mixture*, 2 lbs. sulphate of copper, 3 lbs. carbonate of copper, 3 oz. permanganate of potash, $\frac{1}{2}$ lb. soft soap, and 18 gallons of rain-water (the soap being dissolved in hot water), all the infected ground, and beyond it, being thoroughly wetted.

More or less serious damage is also sometimes done by *Rhizina undulata*, a saprophytic root-fungus, also parasitic on young Conifers on sandy soil, and producing flesh-like, stalkless, velvety sporophores, chestnut brown above and pale below, from 1 to 3 in. long on the roots,—and by *Rhizoctonia violacea*, the heather-fungus, which surrounds young Conifer-roots with a close violet mycelium and produces black warty sporophores on the dead roots.

II. Chief Fungus Diseases in Plantations and Woods.

* *Lophodermium pinastri* (see above) also attacks young Conifer plantations, while *L. macrosporum* attacks the leaves of 2-year-old shoots in Spruce plantations from 10 to 30 years of age, turning them rusty-red

and often making them fall off, and *L. nervisequium* the 2-year-old leaves of Silver Fir branches, turning them brown and causing leaf-shedding.

Remedy.—Spraying or cutting and burning diseased shoots, but neither practicable extensively.

The Larch leaf-shedding disease, *Sphaerella laricina*, attacks the foliage of poles or trees.

Fig. 58.

Larch Canker.

a. Dead wood with resin outflow.

b. Cup-shaped sporophores of fungus.

In June or July infected leaves turn brown-spotted and soon fall off, and in wet years most of the foliage is shed by August. The only way to stop the disease spreading is to

cut and remove infected poles or trees, and burn the diseased foliage, else the small black conidia forming spread the disease in wet weather.

* The Larch canker- or blister-fungus, *Peziza Willkommii* (syn. *Dasyscypha calycina*) (Fig. 58), the most destructive tree-disease in Britain, is saprophytic on dead Larch twigs, and as a parasite chiefly attacks Larch (also Pines and Firs) of 7 to 15 years old. Japanese Larch is still much less liable than common Larch to attacks of insects and of this fungus, though no longer immune. Larch is never immune from attacks, though after thick

bark forms attacks are confined to young branches. It is a wound-parasite, and spores only germinate where punctures or greater wounds have been made by insects, hail, gnawing, &c. The earlier the attack, the more serious it is. Poles of 7 to 12 years are usually badly deformed or killed outright. On older

trees canker-spots may dry up and become partially cicatrised, but the diseased part is spoiled as timber.

The first signs of disease are smooth shining spots or swellings on the stem or branches; then the bark splits, a slight outflow of resin takes place, and bits of bark scale off, while small cup-shaped sporophores with felty white or grey edges and bright orange-red or pinkish-yellow centres appear. The dead parts grow scurfy and black, while the wounds deepen as the bark curls up at the edges, and gradually spread up and down, or else round the stem, thus killing the pole or the crown above the wound.

Remedy.—As infected stems or branches spread the disease, diseased poles should (if practicable) be cut and removed from the woods. The cleaner that plantations are kept, and the more regularly they are thinned, the less favourable are the conditions for the fungus. Pure Larch plantations are almost certain to be more or less attacked, and the only way of securing even partial immunity is to grow Larch in admixture with broad-leaved trees (Beech, if possible). Mixing Spruce and Larch is more likely to spread than to prevent the disease (owing to *Chermes abietis-laricis*, see p. 226).

P. resinaria produces a similar disease on Spruce and *Pinus excelsa* in southern England, and also on Larch, and is only distinguishable by its cup-shaped sporophore being paler in colour, smaller, and more distinctly stalked.

Phoma pithya attacks twigs and branches of Douglas Fir and Pine, destroying the bark and producing constriction round the stem, which dies above if the cambium is destroyed right round, but heals by cicatrization if the stem has not been completely ringed. Infection usually takes place where branches join the stem.—*Ph. abietina* does similar damage to Silver Fir twigs and branches.—*Septoria parasitica* often kills the leaders of common and Menzies Spruces from seedlings up to 30-year-old poles, young shoots infected at their base drooping in May or June, then withering and dying within 7 to 14 days.

The Silver Fir needle-blight, *Trichosphaeria parasitica*, often in damp localities attacks young poles and lower branches of Silver Fir, Spruce, and Douglas Fir, and makes the leaves turn brown, when they hang down,

Fig. 59.

Young Beech stem cankered by *Nectria ditissima*.

- a. Clusters of red sporophores, as seen during winter months.
b. Canker-spots, showing dead wood.

Young Spruce damaged by *Nectria curcubitula*.

- a. Sporophores hibernating on the dead bark.

injuring the bark on the poles or trees left standing.

The Coral-spot disease, *Nectria cinnabarina*, is a common saprophyte on dead branches of broad-leaved trees, and also parasitic on Horse-Chestnut, Lime, Maple, Sycamore, and Elm, destroying the sapwood in rings and killing the parts

held by the mycelium, which perennialises so that the disease goes on from year to year, unless infected twigs are cut and burned (before spores ripen, to prevent disease spreading).

The Canker of broad-leaved trees, *Nectria ditissima* (Fig. 59), chiefly attacks Beech and Ash, making Ash black in the heart and useless, and soon becoming epidemic in Ash-groves, especially on wet land. It can be distinguished from other diseased conditions by small dark-red globular pustules. Growing only parasitically, its spores germinate on wounds made by insects, frost, hail, &c., on young shoots and poles, especially at forks; and the mycelium lives chiefly in the bark, killing infected portions and gradually extending, and canker-spots forming as the dead parts cicatrise, and gradually increase till the pole or tree is killed. *Remedy*.—Infected saplings, poles, or trees should be thinned out without making wound-surfaces by in-

above those infected. On parts attacked saprophytically small conidia-cushions break out of the bark, upon which the vermilion and dark-red spore-bearers appear in autumn and winter. But the mycelium can extend parasitically from wound-surfaces into living branches, soon spreads quickly in the woody tissue, kills the cambium, and prevents the upward flow of sap. *Remedy*.—Infected parts should be cut off and burned before the spores scatter in autumn and spring.

The Spruce-bark Canker, *Nectria curcubitula* (Fig. 59), occurs chiefly as a wound-parasite on young Spruce poles, also Silver Fir, Pines, and Larch, and is common in Britain, though generally only as a saprophyte. On young trees in vigorous growth it remains saprophytic, but in weakly young trees the canker extends, kills the cambium, and penetrates the sapwood. The first signs of the disease are bleaching of the needles, and drying and browning of the bark and cambium, especially near wounds caused by insects, &c. The mycelium spreads quickly in the bark during the winter. Infected parts should be cut and burned in autumn or early winter, before the spores ripen and are shed.

The Maple and Sycamore leaf-blotch, *Rhytisma accerinum*, appears in damp summer weather as small round yellow spots, about $\frac{1}{4}$ to $\frac{1}{2}$ in. broad on the lower side of leaves, that gradually enlarge and turn jet-black in autumn. The spores produced in these black sporophores are scattered from the dead leaves in the following May or June, and are borne by wind to the new foliage, which they attack in the same way as before. It can only be checked by collecting and burning the infected dead leaves in autumn in parks and gardens. It is not a serious disease in woods.

The Rust-fungi (*Uredineae*), so called from their sporophores often assuming a reddish-yellow rusty colour, are all parasitic, and mostly have a change of generation with some other kind of host-plant, upon which they appear like entirely different diseases and have other quasi-generic and specific names. Five different genera of metoxenous (heterœcious) rust-fungi attack our trees, *Melampsora*, *Melampsorella*, *Coleosporium*, *Cronartium*, and *Chrysomyxa*, one species of which is autoxenos (autœcious).

In the genus *Melampsora* the intermediate form is called *Cœoma*, and the chief disease of this kind is the **Poplar-rust** and **Pine shoot-twisting fungus**, *Melampsora pinitorqua* + *Cœoma pinitorquum*, of which the *Melampsora* stage, that producing resting-spores, is passed as yellow patches on the foliage of Aspens and White and Grey Poplars, while the much more destructive intermediate stage is the *Cœoma pinitorquum* (Fig. 60, 61), that breaks out in spring after hibernating on the dead Poplar foliage, and chiefly attacks Pine plantations up to 10 years old. The yellow *Cœoma* pustules, about 1 in. long, burst lengthways, and generally kill young shoots, while older twigs get C- or S-shaped when two pustules break out on the same or on different sides of a twig. The mycelium can perenniate, each year forming new pustules that shrivel up in dry

weather, but develop freely in a wet May or June. Young plantations are thus often injured, until attacks cease at about 30 years old. *Remedy*.—Dry warm weather retards and checks the disease; but the only way to prevent would be to collect and burn all Poplar foliage infected with the *Melampsora*-stage, and all Pine-shoots infected.

Other less important kinds of Poplar *Melampsora* are the *M. larici-tremulæ*, producing resting-

Fig. 60.

Damage to crowns of young Pine by Cæoma pinitorquum, the abnormal bends being caused by the fungus.

spores on Aspen and Poplars, and its Cæoma-form on Larch (*C. laricis*), and *M. larici-populina* on Black Poplars + *C. laricis* on Larch, the Cæoma being similar in both cases, and forming small, bright, orange-yellow pustules on the Larch leaves. There are also several kinds of willow-rust fungi, some of which may in their *Melampsora*-stage greatly damage osiers by making their leaves black-spotted and

Fig. 61.

Damage caused to Scots Pine by Melampsora pinitorqua in its cæoma-form, Cæoma pinitorquum.

γ Bent infected spots, which here happen to be both on same side of twig.

soon shed (Fig. 62), while the Cæoma-stage is spent on Conifer leaves (Pines, Firs, and Larch).

In the genus *Melampsorella* the intermediate form is called *Æcidium*, and the chief disease is *M. cerastii*, producing round orange-yellow pustules on the leaves of plants belonging to the *Alsineæ* family (and especially *Cerastium*, *Stellaria*, and *Holostea*) which develop the resting-spores producing *Æcidium elatinum* on the Silver Fir, either as spindle-shaped cankerous excrescences on the stem, or twig-clusters with yellow-green deformed foliage ("witches' brooms") on branches. It perenniates and often kills trees infected, especially in hot dry years and on sandy soil.

Whether a canker-spot or a twig-deformity will be produced depends on where the spores enter and the mycelium develops, but both are often found on a tree. If infection takes place near a healthy bud, a deformed twig-cluster results; but if the mycelium infects the bark of a shoot, canker is produced, infection being only possible through some wound-surface. The yellow or brownish-orange *æcidiospores* are produced in the diseased leaves of the youngest shoots in the twig-clusters, and appear from June till August on the lower side. The *Æcidium* perenniates and in course of time the canker-swellings and the twig-clusters attain a large size. The disease can only be eradicated by con-

tinuously cutting off and burning the twig-clusters in June and July before their spores ripen by pruning infected branches, by thinning out cankered poles or trees, and by removing and burning the host-plants (*Cerastium*, *Stellaria*, *Holostea*) upon which the *M. cerastii* develops resting-spores.—Another disease of the same genus is *M. betulina* + *Æc.*

Fig. 62.

Willow Rust on Osier.

- a. Green leaf with yellow pustular sporophores.
- b. Dead parts of leaf.
- c. Sporophores on the osier-stem.

laricis, the **Birch-rust fungus** producing resting-spores in orange-red, then brown pustules, and forming reddish-orange *acidia* on Larch leaves.

In the genus *Coleosporium* the resting-spores are produced in yellowish pustules on corymbiferous plants, and especially on Groundsel and Ragworts (*Senecio*), and the intermediate stage is called *Peridermium*, from the bladder-like spore-pustules produced on the leaves of Pines attacked. The commonest kind is *C. senecionis* on groundsel and ragwort leaves + *P. oblongisporium* (formerly called *P. pini acicola*) on the old foliage of 3- to 10-year-old Pines (and up to 30 years), but never on new leaves. In April and May small orange-yellow blisters appear on the leaves of 1- and 2-year-old shoots, which turn brown, burst, and scatter their spores, while the mycelium hibernates in the leaf and again produces *acidia* in the following year, the leaves killed showing small, blackish, warty spots with light edging. The only means of prevention is to dig up and burn all ragwort and similar corymbiferous plants in the immediate neighbourhood, and to cut and burn infected Pine twigs.

Fig. 63.

Pine-shoot with sporophores of Peridermium pini.

- a. Blisters that have not yet discharged their spores.
- b. Ruptured blisters from which the spores have been partly scattered.

* In the genus *Cronartium* the intermediate stage is also called *Peridermium*, as the spores are here again produced in bladders; and to it belongs the several blisters or bladder-rusts on the stems of Pines (formerly called *P. pini corticola*). The chief disease of this genus is the **Pine bark-blisters** (Fig. 63), a *Cronartium species* + *Peridermium pini*, the resting-spores of which are produced in rusts on foliage of peonies, *Ribes*, and *Cynanchum*, and the *peridermium*-stage passed on the

stems of young Pines, and especially on poor soil with a S. or S.W. exposure, where it may become epidemic and do serious damage. It is purely a wound-parasite, and mainly attacks Pine-poles 15 to 20 years old, and thick-barked parts over 25 years seem immune. It mostly appears first at whorls near the top of the crown, and as the oval pustules filled with reddish-yellow spores break out as blisters on the bark of stem and branches in

June, they induce flow of resin, the growth of the tree is interfered with, and often the whole tree above the infected part dies. The mycelium hibernates, but increases year by year, as also the cankerous parts, and in course of time the crown dies, though young poles are often killed during

Fig. 64.

Twig of Spruce attacked by Chrysomyxa abietis.

Fig. 65.

3 to 4 times natural size.

a, b. First appearance of pale yellow marks about end of May or June.

c. Long spore-pustules formed during autumn.

d. The bursting of a spore-pustule in following May.

the first year, and especially in warm dry years. The only way to prevent the disease spreading is to cut out and remove infected poles as soon as possible. The commonest alternative host-plant is not yet known.

Of the genus *Chrysomyxa*, the commonest species is the autoxenos **Spruce leaf-blister**, *Ch. abietis* (Fig. 64, 65), on young Spruce foliage, and mostly low down in 10- to 20-year-old plantations on wet soil and in damp warm places, while 1-year-old or older leaves are immune, and the top of the crown is little attacked. New leaves infected in any year become speckled with pale yellow bands on 1-year-old leaves in May or June of

the next year, and these bands develop into long brown spore-bearing pustules, and gradually redden and swell, but only burst and scatter the spores in the following April and May to infect the new foliage. The only remedy is cutting and burning infected twigs, and careful thinning.

* **The Pine Stem-rot fungus, *Trametes pini*** (Fig. 66), a wound-surface parasite, chiefly attacks Pines about 40 years old or more, also Spruce, Larch, and Silver Fir, as wounds on younger trees usually close up by resin-outflow before the fungus can obtain a firm foothold. The *hyphæ* destroy the cell-walls of the woody tissues and enter the heartwood; and the mycelium extends up and down the stem, forming long *ring-* or *heart-shakes*, and soon producing rot, while the sapwood usually remains un-

Fig. 66.

About $\frac{1}{2}$ natural size.

Rot in Pine caused by Trametes pini.

a. Bracket-shaped sporophore.

infected. In Pine and Larch only the heartwood is rotted, but in Spruce and Silver Fir all the stem rots. The diseased wood first becomes reddish-brown, then white patches appear here and there, and the mycelium issues from branch-holes or through the bark, and forms a brown, corky-woody, bracket-

shaped sporophore, which lives for many years, showing concentric ridges, and varying up to about 10 in. diameter. Infected trees should be thinned out; and any Conifers pruned should have the wound-surfaces well tarred.

* **The Red-rot Root-fungus, *Fomes annosus*, syn. *Trametes radiciperda*** (Fig. 67), chiefly attacks the roots of Pines from about 5 years old upwards, and also other Conifers, and spreads centrifugally from root to root. It is sometimes found on roots of broad-leaved trees (especially Beech and Birch), but is not then so destructive or so apt to become epidemic as in Conifer plantations. Young plants, poles, and trees attacked soon show pale needles and stunted shoots (as also in attacks of *Agaricus melleus*), then rot near the roots and die suddenly, and the disease quickly spreads, infection taking place wherever a diseased root comes in contact with

the roots of a healthy tree. The roots then die, the diseased wood turns violet and pale brown-yellow with black spots surrounded with a white zone, then hollows become excavated, and the whole rots. But infection can also be conveyed to wound-surfaces on the roots of healthy trees by mice, insects, &c. The soft, transparent, or snow-white mycelium develops beneath the bark and permeates the cambium and the woody tissue of the roots and the butt of the tree, the cell-walls being destroyed by masses of mycelial filaments. This rottenness soon spreads up into the stem by the cambium and the medullary rays—except in the Scots Pine, in which morbid resinification confines the rot to the butt. Destroying the living cells as it spreads, the mycelium soon penetrates the wood of the roots and extends more slowly into the bark, where it forms long thin tissue-paper-like strands, with small yellowish-white pustules protruding between

Fig. 67.

Half natural size.

Sporophore of Fomes annosus on Scots Pine root.

bark-scales, these being a sign that the disease has complete hold of the tree. The mycelium can now spread and carry infection to neighbouring plants or trees. Small, glossy, yellowish-white, grape-like masses of sporophores appear mainly on the roots or at base of stem between the bark-scales, and form thin concave woody chocolate-brown cushions, snow-white below, which unite with similar adjoining groups as flat incrustations or bracket-shaped excrescences up to a foot broad. But mould-like masses of conidia are also produced where the mycelium comes out into free air.

Remedy.—Direct spore-infection can hardly be prevented; but when the disease has broken out, the diseased plants should be grubbed up and the infected parts burned before the sporophores ripen, and broad-leaved trees planted in place of the Conifers lifted. Infected patches isolated by narrow trenches usually produce sporophores on the roots cut through,

so that this measure is only advisable where they can be collected and burned before they ripen and scatter their spores.

The White-rot fungus, *Fomes igniarius*, is one of the commonest wound-parasites on broad-leaved trees, and chiefly Oak and Willows. When infected, wood turns brown, then yellowish-white, and the spongy sporophores form a cap or bracket up to 10 or 12 in. broad. At first yellowish-

Fig. 68.

Young Scots Pine killed by Agaricus melleus.

- a. Branching subterraneous rhizomorphs thrown out from the mycelium under the living bark.
- b. Abortive sporophores produced at extremity of a rhizomorph.
- c. Normal sporophores produced at extremity of a rhizomorph.
- d. Sporophores produced in a cluster from the bark at base of stem of the dead Pine.

brown and felty, they afterwards turn blackish-brown and smooth with concentric ridges, the openings of the spore-tubes being cinnamon-brown. Its spongy sporophore was formerly (as well as *F. fomentarius*) used as tinder (hence *igniarius*) in the days of flint and steel.—*Fomes fomentarius* is a wound-parasite on Beech chiefly, also Oak and Elm, where its broad leathery mycelium, penetrating the wood radially, also produces "white-rot." It forms large, hoof-shaped, russet-brown or greyish sporophores,

sometimes over 3 ft. long, with a hard upper crust and soft spongy inner tissue.—Many other species attack broad-leaved trees.

Polyporus sulphureus is a “red-rot” wound-parasite on Oak, Willows, Poplar, and Birch chiefly, also other broad-leaved trees, and Conifers. The large, fleshy or cheese-like, bright sulphur-yellow or reddish-yellow sporophores appear annually at old branch-holes or on the stem, assuming different forms, and varying up to 2 ft. long.—*Polyporus vaporarius* is another “red-rot” wound-parasite chiefly in Conifers, and also destructive as a saprophyte in timber lying in the woods (like *Merulius lacrymans*, which is seldom parasitic; but the mycelium of the latter soon changes from white to grey, while that of *P. vaporarius* always keeps white). Its sporophores form flat, thin, white incrustations on the bark of the trees infected.

* **The Beech Stump-tuft or common Agaric**, *Agaricus melleus* (Figs. 68, 69), an edible mushroom growing saprophytically on dead stools and roots of old trees (especially Beech), is a common and often very destructive parasite in young

Conifer crops, especially Scots Pine, and mostly attacks plantations of 4 to 15 years old. As first signs the leaves of the infected plant, pole, or tree turn yellow, wither, and fall; then the shoots wither and the butt of the stem swells, the bark fissures, resin exudes and flows to the ground, the cambium is killed, and finally the infected poles or trees usually die either in spring or in autumn, while rhizomorphs pervade the rotting wood and the soil round about, even when no tawny yellow mushrooms appear.

This disease breaks out in patches and rapidly kills young plants in full vigour. The honey-yellow or dirty yellow-brown mushrooms (*pilei*) with dark-brown hairy scales and yellowish-white lamellæ, which turn flesh-coloured, or on which reddish-brown spots form later, appear in

Fig. 69.

Natural size.

- a. Part of a Scots Pine root killed by *Agaricus melleus*, and showing an external rhizomorph penetrating the root at a.
- b. Flattened internal rhizomorph from between bark and dead wood.

October, and are most numerous in damp seasons, the pale flesh-coloured stalk of the mushroom showing a yellowish-white ring of skin at the point of rupture below the cap. The white spores produced in autumn develop long branching purplish or brownish-black cord-like strands (*rhizomorpha*) spreading singly like rootlets throughout the soil, as well as below the bark of the dead stump saprophytically attacked, which invade the tissues of the roots they come in contact with; and (as in *Fomes annosus*) the rhizomorphs from diseased roots spread around and attack the roots of healthy trees, so that the disease becomes centrifugal and epidemic. The disease can only be prevented or checked by collecting the mushrooms saprophytic on stumps, and pulling up and burning all the roots of infected trees, and filling up the blanks with broad-leaved trees. Infested patches can be isolated by trenches 1 to 1½ ft. deep, but this will only be efficacious if the fructifications of the rhizomorphs can be collected along the inside of the trench before they ripen.—Another species of Agaric, the Beech branch-tuft, *A. mucidus*, appears chiefly at branch-forks of Beeches.

CHAPTER IV.

PROTECTION AGAINST DAMAGE FROM INORGANIC CAUSES.

Non-parasitic Diseases or serious physiological disturbance predisposing trees to disease can be caused by injurious influences in soil or atmosphere.

The **Soil** may be unfavourable through being too shallow, dry, or wet. A **dry soil** is naturally poor in the amount of plant-food in an available soluble form, and consequently the crops are usually backward, stunted, and likely to become attacked by insects and fungus diseases. **Stagheadedness** or partial or total death of the crown, often the first stage of decay from old age, is frequently induced by want of water and nourishment in the subsoil, though also common when Oaks and other trees are heavily thinned after growing long in close canopy, or when standards over coppice are pruned of lower branches; for shoots flush along the stem and intercept the sap on its upward flow. Stagheadedness also often follows any sudden lowering of the water-level in the soil, by drainage, railway-cuttings, &c.; and Willows and Poplars soon become stag-headed on dry soil. Stagheaded broad-leaved trees often live for many years, but Conifers soon die. Trenching round and filling up with manure afford a temporary remedy for old ornamental trees. A **stiff soil** and a **wet soil** that has not been well drained before planting are both deficient in oxygen, so that the roots get suffocated and rot away, especially in the

case of the tap-roots in young Scots Pine plantations. And even when the land is not wet, if the natural drainage be not good the butt becomes spongy and dosed, and pumped or hollow, as is often found in 60- to 80-year-old Larch that have grown well and rapidly up to about 50 or 60 years of age. Such red-rot and dosed condition is common in most middle-aged or old Conifer crops where a thin gravelly soil rests on a clayey or impervious subsoil. On a wet soil there is also great danger from **frost**, and from **windfall** if the roots cannot penetrate into the subsoil. The only remedy is to drain the land before planting, or to plant only trees that do best on a moist soil (Alder, Willow, Poplar, and Spruce on mounds); but stagnating moisture is always injurious.

Other unhealthy conditions induced by unsuitable soil or situation are **premature seeding** and **bark-binding**. Premature seeding is a sure sign that the individual tree is not in a healthy condition, yet nothing can be done to prevent this natural effort of reproduction; but bark-bound stems can often be relieved by making a cut through the hard, dry, leathery-like bark lengthways down the stem in early summer, unless the disease is of long standing and the bark has lost its natural elasticity.

Injurious atmospheric influences may cause damage in nurseries, young plantations, and older woods by wind, frost, heat and drought, heavy rainfall, snow, hail, ice and hoar-frost, and poisonous gases.

Winds and gales are always most destructive when coming after heavy rainfall, which loosens the soil and weights the tree-crowns. Gales from S.W. are frequent about the equinoxes (March and September), but the most destructive storms usually come from the W., N.W., or N.E., according to the local situation. The damage consists in breakage of branches and stems, or in single trees, or clumps, or whole woods being blown down (*windfall*) in the track of the cyclone, while neighbouring

woods may be comparatively little injured. The extent of the damage done varies with the kind, age, and density of the crop; and heavily-thinned woods are more likely to be thrown than those in close-canopy, when the tree-crowns afford each other a slight support. The best means of preventing damage have already been indicated in Part II. (see pp. 120 to 123). Wind-fall and broken trees should be extracted as soon as possible, to prevent insect attacks; and to shorten the time of the land lying unproductive, roads and rides should be prepared for immediate extraction of timber. In natural regenerations, where the roots of standards have torn up great masses of soil, the butts should be sawn through and the stumps tilted back into their former position, if possible, to save the seedlings. Conifer windfall timber will get soon attacked by insects unless barked; and weevils will breed enormously, and hinder replanting for 3 or 4 years, unless the stumps can be grubbed up.

Frost may do damage in spring (*late frost*), autumn (*early frost*), or winter (*winter frost*). In any frost-bitten part of a plant, water expands beyond the cells and into the intercellular spaces, the cell-tissue loses its tension, and the affected parts wither and die. **Late frosts** in spring are often very destructive in nurseries, seedlings being killed and transplants losing their young shoots, and in young plantations many deaths are caused, especially in damp, low-lying, sheltered spots (*frost-holes*), where there is no current of air to carry away the cold layers. **Early frosts** in autumn nip young shoots before they harden properly, but seldom kill the plant outright, though often causing leaf-shedding in young Conifers (like that in Pine due to the fungus *Lophodermium pinastri*). **Winter frosts** lift the soil and the plants in nurseries, especially when a stiff soil is wet, and in young plantations, and make frost-cracks in trees. Among broad-leaved trees Ash, Chestnut, Beech, Robinia, and Sessile Oak, and among Conifers, Silver Fir, Pacific Douglas Fir, Menzies Spruce, and Maritime Pine

are the least hardy against frost; while the most hardy are softwoods, Hornbeam, Pines, and Colorado Douglas Fir. Alder, Birch, and Hornbeam flush their leaves earlier than the less hardy Oak, &c.; and Silver Fir side-shoots are often killed, while the leading-shoot escapes, as the terminal bud is the last to develop. Larch is sensitive just when the buds are opening, but hardy after the leaves expand.

Damage from late frosts in nurseries can best be prevented by selecting sites with a N. or N.W. aspect, or protected on E. and S. by old woods, and preferably broad-leaved; and young seedlings and transplants are best protected by a horizontal framework of thin laths about 1 in. broad set 1 in. apart. In planting land exposed to frost, any existing protection, such as heather, &c., should be made use of as long as required; or hardy quick-growing trees like Birch, Larch, Pine, and White Alder can be planted as **nurses** to protect less hardy kinds—and if practicable they should be planted a year or two in advance; but they should be cut out in the weedings and early thinnings when they have served their purpose and are no longer needed to protect the other kinds of trees intended to form the timber-crop. When soil and seedlings are lifted in nurseries by hard winter frost, only the soil sets when the thaw comes, so that the roots are more or less exposed and have to be banked up, and the young plants are sometimes lifted so high that they fall over and soon die unless replanted, as is often the case (except with deep-rooting seedlings like Oak, Chestnut, and Pine). Drill-sown beds suffer less than broad-sown, and the danger of lifting is decreased by putting sawdust, moss, or loose earth between the drills. Broad-leaved saplings badly frost-bitten can be cut back to shoot from the stool, and blanks in Conifer plantations should be beaten up with hardy quick-growing trees (Birch, Aspen, Pine).

Frost-shakes or **Frost-cracks** are longitudinal fissures on the lower part of the stem, and especially of 50- to 70-year-old Oak,

caused by rapid shrinkage of the bark and sapwood during intense frost, a sudden rupture of the woody-fibrous tissue taking place along the line of least resistance, usually accompanied by a loud noise. The clefts or frost-shakes, often only about a yard long, sometimes extend all along the bole and go deep into the tree. When the thaw occurs, the woody-fibrous tissue expands and almost closes up the wound, which cicatrises by a ridge of callus tissue. This may be repeated every winter, or the cleft may remain closed during mild winters; but the frost-shake remains visible as a long swollen ridge, spoils the timber, and enables fungus-spores to enter: rot is therefore frequent near frost-shaken parts.

Frost-cracks are mostly to be found on trees with large medullary rays (Oak, Elm, Chestnut), but also occur on Beech, Ash, Maple, Sycamore, Lime, Poplar, and Willow. Conifers are seldom split by frost, though cracks are sometimes to be seen on Spruce and Silver Fir.

Heat causes **sun-burn** or **bark-scorching** by direct insolation, whereas **Drought** impoverishes a dry soil by exhausting the soil-moisture through evaporation, though warmth stimulates the activity of vegetation so long as there is a sufficiency of soil-moisture obtainable from percolations, capillarity, or rainfall. But when transpiration from foliage is increased by warmth and dry winds, without ample water-supply being obtained from the soil, the natural balance between imbibition and transpiration is disturbed, leaves droop and wither, and even in the usually damp climate of the Western Highlands many deaths are thus caused during a warm, dry, windy May and June, especially when there is no growth of heather, &c., to protect the young plants in new plantations until they have established themselves and got their roots down well into the lower soil where the supply of soil-moisture is more constant than nearer the surface. And, of course, in sandy districts the danger of fire is always great when July and August

are dry months. The best protection against drought is to retain the protection of existing trees, heather, &c. (so long as required), or to plant nurses (as for protection against frost) and remove them as soon as no longer needed. **Sunburn** or **bark-scorching** by direct action of the sun makes patches of bark on S. or S.W. sides of stems dry, crack, and fall off, and the wood below that rot ; and this occurs oftenest when trees are suddenly exposed to full sunshine. Smooth-barked trees are most easily scorched, and rough-barked trees (Oak, Elm, &c.) have the best natural protection. So far as practicable, the S. and S.W. edges of maturing crops should not be suddenly exposed ; but sun-burnt stems along the edge should not be cut, as the trees behind them will be just as likely to get scorched.

Heavy rainfall erodes the soil and carries away the finer particles of earth and much of the beneficial humus, though the action of woods in close canopy is to reduce such damage to its minimum. **Snow** only damages trees if falling in large quantities, by causing the branches to be bent down or broken off. Of our common Conifer trees the brittle Scots Pine is most liable to damage from snowbreak ; while among broad-leaved trees Beech, Alder, Crack Willow, and Robinia have the brittlest branches. In Central Europe, where snow falls heavily and lies long, young Spruce, Oak, and Beech woods are sometimes laid by snow-pressure, but this is seldom likely to occur in Britain. Damage from snowbreak may occur anywhere or all over in Scots Pine woods ; but in other kinds of tree-crops it is chiefly confined to the edges of compartments, or to small patches here and there. Heavy snow can be taken off young ornamental trees in parks, avenues, or small plantations, by shaking the poles or tapping them with a padded mallet ; but in woodlands this is impracticable, and the only way of preventing damage is to tend the woods carefully, especially with regard to moderate thinning.

Hail-storms beat down, injure, and often kill young plants in nurseries, besides making surface-wounds on the young shoots of older trees and thus enabling the spores of fungus diseases to effect an entrance. Oak-bark will not strip at damaged spots, and much damage is done to Osier-beds in the fen districts, as the withes do not peel freely, and break at the injured parts. The only remedy is to cut back badly-damaged broad-leaved saplings, and to fill blanks in older crops with stout plants of any suitable kind.

Ice and **Hoar-frost** do damage in mountain-tracts to brittle-branched trees like Scots Pine and Alder, and greatly increase the danger of serious damage should snow fall while the twigs are frozen, and especially in evergreen Conifer crops. Mixed woods suffer less than pure crops of Scots Pine.

Lightning does practically no damage in woodlands, though here and there a tree may be struck and badly damaged or killed; but park-, field-, hedgerow-, and avenue-trees are more often struck and blasted.

Among **atmospheric impurities** the particles of **carbon in city smoke** choke the pores of the leaves, while **poisonous gases** from factories and smelting-works, and even from railway trains running frequently through wooded valleys, are always more or less injurious to trees and woodlands, the cause of damage being mainly the sulphurous acid contained in the smoke, which changes the natural colour of the leaves and kills off many poles and trees. But nitrous, hydrochloric, and arsenious gases cause similar damage, though to a less extent; and the damage is always greatest in damp localities. When dew or rain falls on a leaf-surface, in a smoky locality, the sulphurous acid combines with the water, oxidises into sulphuric acid ($\text{SO}_2 + \text{H}_2\text{O} + \text{O} = \text{H}_2\text{SO}_4$), and acts very injuriously on the leaf-tissue, especially of evergreen Conifers. In broad-leaved trees the leaves become mottled with damaged patches (sulphuric acid) or discoloured at the edge (nitric and hydro-

chloric acids), while Conifer-leaves turn yellow or red at the tip before the whole needle is poisoned, discoloured, and killed. And usually, too, in smoky localities Pine pole-woods are very liable to attack by the leaf-shedding fungus, *Lophodermium pinastri*. Under the Alkali Acts steps may be taken to prevent hydrochloric acid issuing in injurious quantities from works; but the only practical remedies in woodlands exposed to atmospheric impurities of any sort are to try and grow broad-leaved crops, to maintain thick shelter-belts of hardy trees on the side from which smoke comes, and to make occasional falls, annually or periodically, rather than clear falls and replantation. But where woods or plantations have been destroyed by atmospheric impurities, the sowing or planting of smoke- or gas-poisoned blanks is useless.

PART IV.

THE

UTILISATION OF WOODLAND PRODUCE

CHAP.

- I. TIMBER : ITS STRUCTURE, IDENTIFICATION, COMPOSITION, TECHNICAL PROPERTIES, PRACTICAL USES, AND MARKET VALUE.
- II. THE HARVESTING OF WOODLAND PRODUCE, AND ITS PREPARATION AND SALE.
- III. TIMBER-TRANSPORT BY LAND AND WATER.
- IV. THE SEASONING AND PRESERVATION OF TIMBER.
- V. WOODLAND INDUSTRIES : ESTATE SAWMILLS, PREPARATION OF WOOD - PULP AND CELLULOSE, CHARCOAL - MAKING, RESIN-TAPPING, ETC.

CHAPTER I.

TIMBER : ITS STRUCTURE, IDENTIFICATION, COMPOSITION, TECHNICAL PROPERTIES, PRACTICAL USES, AND MARKET VALUE.

Timber has no generally accepted definition. As distinguished from fuel, it is wood used for any technical purpose. For railway freight it includes "all descriptions of wood in an unmanufactured, or roughly hewn, or roughly sawn state ; but not any wood shaped, or prepared, or partially prepared." As distinguished from coppice, with or without standards, it in English law includes all woods and trees not cut in regular rotation ; though Beechwoods in England, cleared and naturally regenerated every ninety to one hundred years, can be used by the heir-in-possession of a settled estate, through local habit and custom, without impeachment for waste — a restriction not applying to timber on Scottish entailed estates. Again, in selling trees, local custom usually classes as timber only what measures not less than 5 or 6 in. in quarter-girth (20 to 24 in. in girth) under bark, or frequently in Scotland to 6 in. in diameter free of bark ; while pitwood is measured down to 2½ in. diameter under bark, or 3 in. over bark at the thin end. Tops and branches below the local customary timber dimensions are not paid for (see also Part II., pp. 89-91).

The technical properties of timber depend mainly on its *anatomical structure* and its *chemical composition*, and are evidenced in its *outward appearance*, its *material condition*, and its *relation towards external influences*.

I. As regards **Anatomical Structure**, the woody tissue of trees consists of (1) *woody fibres*, (2) *wood-vessels*, and (3) *wood-cells*, with a framework of cellulose. (1) The *woody fibres* are elongated, pointed at both ends, and thick-walled; and they are formed of hard tissue (*sclerenchyma*) with walls dotted with small pits, and of tubes (*tracheids*) with large internal spaces (*lumina*), whose walls are dotted with large bordered pits; and sometimes there is also a subordinate form of wood fibre shaped like true hard tissue, but filled with protoplasm, starch, and other substances. (2) The *wood-vessels*, seen as pores on making a transverse section, are long narrow tubes closed at both ends, with thin walls and large lumina. (3) The *wood-cells* forming soft tissue (*parenchyma*) are thin-walled, more or less cubical, and mostly with flattened ends; and they are chiefly found near the vessels, where they serve for storing reserve nutrients (starch, &c.) for reproductive purposes (new foliage, flowers, fruit, &c.), while the sap is conveyed through the woody fibres and the vessels.

The wood of broad-leaved trees contains all the above kinds of woody tissue, while that of Conifers differs from it in having no large pores (wood-vessels). Hence, the larger the relative proportion of hard tissue, the heavier, harder, and stronger is the wood of any given kind of broad-leaved tree; and the larger the proportion of thick-walled tracheids with small lumina produced during the warm summer weather, as compared with the thin-walled tracheids with large lumina forming the softer inner zone produced in spring, the heavier, harder, and stronger is the wood of any given kind of Conifer. In Conifers, wood-cells are found only around the resin-ducts in the *Abietineæ*, and are sparsely scattered throughout the tracheids in the other kinds. But both broad-leaved and Conifer trees have *medullary rays*, formed of wood-cells, extending radially from the central pith (or some annual ring near it) to the bark, which serve partly for storing reserve nutrients in winter (for leaf-produc-

tion, &c., in spring), and their number and size affect the technical properties of timber. In Conifers they are narrow and close, giving a sort of silky gloss to a thin transverse section; but in broad-leaved trees they are usually more prominent, being largest of all in Oak, where they form the "flowering" when planks are cut radially to show "the silver side." The medullary rays are broadest in Oak and Beech, and highest in Oak and Alder; fairly broad in Ash, Elm, Maple, Sycamore, Plane, and Hornbeam; narrow in Alder, Birch, Cherry, Chestnut, Horse-Chestnut, Lime, and Robinia; and almost indistinguishable in Willows and Poplars. The wood of Conifers differs further from that of broad-leaved trees by usually having resin-ducts or tubular spaces surrounded by resin-producing cells without definitely constructed walls. These resin-ducts are not only found running longitudinally in the stem and branches, usually in the summer zone of wood, but also occur along the medullary rays. Both of these two kinds of resin-ducts communicate with each other, and the total quantity of resin stored up in the wood has a great influence on its technical properties.

The width of each annual ring of wood varies with the soil and situation, and with the amount and intensity of light during the growing-period; and the annual rings are usually broader in young and middle-aged than in old trees, while they are always broadest near the butt of the stem; but the best class of timber is that in which the breadth of the successive annual rings is fairly equal, and where the annual rings have a relatively broad dense zone of summer wood formed during the warmest time of the year.

In Conifers the annual rings are usually very distinct, and also in Oak, Ash, Elm, and Chestnut; but in Beech, Hornbeam, Maple and Sycamore, Lime, Willow, Poplar, and Birch, there is little difference between the Spring and the Autumn zone in each annual ring.

IDENTIFICATION OF THE COMMONEST KINDS OF BRITISH
TIMBER FROM ITS ANATOMICAL STRUCTURE, AS SHOWN
BY THE EXAMINATION OF A SMOOTH TRANSVERSE
SECTION :—

A.—BROAD-LEAVED TREES—MEDULLARY RAYS AND PORES USUALLY
EASILY VISIBLE.

I. *Autumn zone denser than Spring zone, and vessels in Spring zone forming a distinct circle of pores.*

1. Medullary rays numerous and wide, forming light-coloured radial bands; pores in radial lines often branching obliquely; wood yellowish-brown to greyish-brown (darker than Sweet-Chestnut)

OAK.

2. Medullary rays narrow, and hardly or not at all visible to the naked eye.

- (1) Wood pale yellowish-brown (paler than Oak, and without wide medullary rays); fine vessels in Autumn wood arranged in radial lines SWEET-CHESTNUT.

- (2) Wood dark reddish-brown (darker than Ash); the fine vessels in Autumn zone forming wavy lines in more or less concentric parallel bands ELM.

- (3) Wood yellowish to light-brown (paler than Elm); seen through a lens, the fine vessels in Autumn zone appear few and fairly regularly distributed; pores in short concentric arcs ASH.

II. *Autumn zone hardly distinguishable from Spring zone, and vessels scarcely visible to the naked eye.*

1. *Some of the medullary rays broad and easily visible, the rest scarcely distinguishable.*

- (1) Medullary rays with silky lustre; wood pale reddish-brown (darker than Hornbeam) BEECH.

- (2) Medullary rays dull and indistinct; wood yellowish-white (paler than Beech) HORNBEAM.

- (3) Medullary rays broad, and annual rings incurving where crossing these; no heartwood; wood white when fresh, pale-brown or brownish-red when dry, and with numerous brown pith-flecks ALDER.

2. *Medullary rays all very narrow, but visible as very fine distinct lines.*

- (1) Wood whitish or pale-yellow, with satin lustre, and hard; annual rings bounded by fine regular lines SYCAMORE.

- (2) Wood closely resembling Sycamore, but somewhat browner or redder MAPLE.

- (3) Wood whitish or reddish-white, soft and light, and of very even texture; boundary of annual rings indistinct (softer than Horse-Chestnut) **LIME.**

3. *Medullary rays invisible to naked eye.*

(1) *With distinct heartwood.*

- (a) Sapwood white or reddish-white; heartwood pale-red to dark-brown, light, soft, and lustrous . . . WILLOW.
(b) Sapwood white; heartwood yellowish or light-brown when fresh, and brown when dry (see also ASPEN) . . . POPLAR.

(2) *Without distinct heartwood.*

- (a) Wood dingy white, soft and light, often with pith-flecks
near centre of stem ASPEN.
- (b) Wood yellowish or reddish-white, and fairly hard and heavy ;
pith-flecks numerous near centre of tree ; annual rings
with fine clear boundary-line BIRCH.
- (c) Wood white, yellowish-white, or reddish-white, and not very
soft (not so soft as Lime) HORSE-CHESTNUT.

B.—CONIFEROUS TREES — NEITHER MEDULLARY RAYS NOR POROUS RINGS OF VESSELS ARE VISIBLE WITH THE NAKED EYE, BUT THE ANNUAL RINGS ARE VERY DISTINCT, THE HARDER AND RUDDIER OR DARKER AUTUMN ZONE BEING PLAINLY DISTINGUISHABLE FROM THE SOFTER AND PALER SPRING ZONE.

I. *Wood with resin-ducts.*

1. Heartwood about same colour as sapwood, pale yellowish or reddish-white ("White deal"); resin-ducts few and fine, appearing as light spots in the Autumn zones; only recognisable from Silver Fir by the resin-ducts SPRUCE.
2. Heartwood reddish-brown when seasoned, sapwood pale yellow or yellowish-white ("Red deals" or "Baltic redwood").
 - (1) Sapwood broad, and branch-knots regularly disposed in whorls; Autumn zone of annual ring somewhat paler red than in Larch, but resin-ducts larger and more numerous and distinct
SCOTS PINE.
 - (2) Sapwood narrow, and branch-knots scattered irregularly (owing to absence of regular branch-whorls).
 - (a) Autumn zone of annual ring darker red than in Scots Pine, but resin-ducts smaller and less numerous . . . LARCH.
 - (b) Heartwood and sapwood both resembling Larch, but more of a pink-red or red-brown colour; resin-ducts small
DOUGLAS FIR.

II. *Wood without resin-ducts.*

1. Heartwood about same colour as sapwood, pale-yellowish or reddish-white ("White Pine"); only recognisable from Spruce by not having resin-ducts SILVER FIR.
2. Heartwood distinctly darker than sapwood; annual rings very clearly marked by a narrow line of compact Autumn wood (CYPRESSES).
 - (1) Sapwood yellowish-white and narrow; heartwood pale brown (*Thuja gigantea*) RED CEDAR.
 - (2) Sapwood whitish; heartwood light pinkish-red or brownish-red (*C. macrocarpa*) MONTEREY CYPRESS.
 - (3) Sapwood yellowish; heartwood pale yellowish-brown (*C. Lawsoniana*) LAWSON'S CYPRESS.

II. As regards Chemical Composition, green wood consists usually of about 50 to 75 per cent of woody substance, and 25 to 50 per cent of sap or water containing organic and mineral substances in solution and suspension; and even after being seasoned or air-dried, from 10 to 12 per cent of the weight of wood consists of water. The framework of the woody fibres, vessels, and cells is cellulose ($C_6H_{10}O_5$), with a composition of about 44 carbon, 6 hydrogen, and 50 oxygen per cent, which during a process called *lignification* loses oxygen and absorbs more carbon along with nitrogen and mineral substances. But the elementary composition of the dry woody substance varies only slightly in different woods, the rough average consisting of the following percentages: 50 carbon, 42 oxygen, 6 hydrogen, 1 nitrogen, and 1 ash or incombustible mineral substances, consisting chiefly of lime, potash, magnesia, and phosphoric acid, the amount and composition of which vary, of course, according to the kind of tree, and the soil, situation, and climate. The organic and the mineral substances in solution or in suspension in the sap are either parts of the cell-wall or products of its transformation, and include protein or nitrogenous matter, carbohydrates, and glucosides; oils, resins, and aromatic substances; tannic, oxalic, and other acids; and dyestuffs; and these combine to give the

different parts of the tree, and especially the heartwood, their own peculiar and distinctive colour, aroma, and technical properties. Some trees form a harder and darker-coloured heartwood (*duramen*) of inert tissue, which is heavier, more thickly stored with organic and mineral substances, and more durable than the younger zone of sapwood (*alburnum*).

It is through the sapwood that the sap ascends from the roots to the crown of the tree for elaboration in the foliage; and on the descent of the elaborated sap through the cambium, part of it is used in adding a new layer of sapwood to the already existing sapwood, while part is also used in forming a new layer of bark (*liber*) to the outer protective covering. If a ring or girdle be cut through the sapwood into the heartwood, the tree is at once killed, because the upward course of the sap is completely arrested; but this operation is more or less ineffective in trees where the sapwood shows little or no visible change in the older and inner part of the stem (*e.g.*, as in Birch, Aspen, Lime, Alder, Maple, Sycamore, Plane, and Hornbeam). The sapwood is usually softer and less durable than the heartwood; and the smaller the proportion of sapwood in any log of timber, the more valuable and durable the timber usually is.

With regard to the presence or absence of a more or less distinct heartwood, our timber-trees may be classified as follows:—

Heartwood trees: Oak, Elm, Chestnut, Robinia, Larch, Pine, Douglas Fir, Cypressess.

Trees with Imperfect Heartwood: Ash, Beech, Willow, Poplar, Horse-Chestnut, Spruce, Silver Fir.

Sapwood trees: Birch, Alder, Maple, Sycamore, Hornbeam, Lime, Aspen.

Heartwood trees can easily be killed by ringing or girdling them—*i.e.*, cutting through the sapwood into the heartwood.

III. **The Ornamental Properties of Timber** are its *colour, lustre, grain, texture, and marking*. When green or freshly

sawn, timber is lighter in colour than when seasoned and long exposed to the air ; and steaming always darkens its natural colour. Woods used for ornamental purposes, such as furniture, wainscotting, &c., are chiefly selected on account of their colour, texture, and marking ; and the coarser the grain of the wood, the more the texture and the marking are displayed (as in Oak, Elm, and Ash), while the greatest variety of marking is shown on a radial section fully exposing the medullary rays (*e.g.*, the “flowering” of Oak). But the coarser the grain, the better a wood takes a polish, as the material used settles easily in the pores. Forked growth and abnormal “burr” excrescences increase the value of timber for ornamental purposes, though depreciating it for building and construction.

The usual colour of sound wood is as follows :—

Colour.	GREEN WOOD.	SEASONED WOOD.
Yellowish-white .	Birch, Spruce, Silver Fir.	...
Whitish-yellow . .	Willow, Poplar.	Birch, Silver Fir.
Yellow	Robinia.	...
Greyish-yellow . .	Ash, Beech, Maple, Sycamore, Hornbeam.	Willow, Maple, Sycamore.
Reddish-yellow . .	Larch, Douglas Fir, Scots Pine.	Beech, Hornbeam.
Brownish-yellow .	Oak, Scots Elm, Chestnut.	Spruce.
Yellowish-brown .	Mountain Ash.	Chestnut, Poplar, Robinia, Ash, Cherry.
Brown	...	Oak, Elm, Mountain Ash,
Red-brown	English Elm, Alder.	Larch, Douglas Fir, Scots Pine, Alder ; Apple, Plum.
Dark-brown . . .	Walnut.	Walnut.

IV. The Physical Properties of Timber, upon which its mechanical properties directly depend, and which are therefore of far more importance than its outward appearance, are (1) *its density and weight*, (2) *the amount of water it contains*, or the extent to which it is seasoned, (3) *its relation towards drought and moisture*, as to shrinking, cracking, splitting, warping and

expanding, and (4) *its freedom from defects and unsoundness*. All these physical properties continually act and react on each other; for the dryness or moistness of the wood affects its density or specific weight as well as its total volume, and also the direction in which shrinkage and expansion occur under dry and moist conditions of the atmosphere.

1. AS REGARDS DENSITY AND WEIGHT, the specific weight of the pure woody substance (exclusive of *lumina* and other hollow spaces) in our woodland trees averages about 1·5 both for heartwood and sapwood; but the specific gravity per cubic foot of wood varies greatly for different kinds of trees, and for any given kind it also varies greatly in the green and the seasoned conditions. For technical purposes it is only the seasoned weight that is important, as green timber is not used. As to average weight when seasoned, British timber may be classified thus :—

Heavy * (sp. gr. 0·7 to 0·75 ; 1 cb. ft. = 44 to 47 lbs.) : Oak (47 lbs.), Ash, Beech, Hornbeam, Maple, Robinia, Elm (44 lbs.).

Medium weight * (sp. gr. 0·6 to 0·7 ; 1 cb. ft. = 37 to 44 lbs.) : Sycamore, Chestnut, Birch, Larch, Colorado Douglas Fir, Red Cedar (Thuja).

Light * (sp. gr. 0·45 to 0·6 ; 1 cb. ft. = 28 to 37 lbs.) : Horse-Chestnut, Alder, Pacific Douglas Fir, Pine, Spruce, Silver Fir, Willow, Aspen, Poplar, Lime, Cypress, and most other Conifers.

* *While green and sappy, timber is usually more than one-third heavier than it will afterwards be when sawn and seasoned.*

2. AS REGARDS MOISTNESS OR DRYNESS, on the average green timber contains sap or water to about one-half of its total weight (42 per cent in hardwoods, 52 in softwoods, and 57 in Conifers); and it still retains water to about 10 per cent of its weight *when thoroughly seasoned* (8 to 10 in broad-leaved, and 10 to 12 in Conifer wood, or more if very resinous). To save time and money, the more valuable kinds of furniture woods are now usually dried in hot-air chambers, as this does not affect their strength; otherwise seasoning takes two to four years for barked

logs, and splitting and warping are likely to occur if logs are sawn into planks before seasoning.

3. AS REGARDS RELATION TO WATER, upon which shrinking, cracking, splitting, warping, and expansion depend, wood shrinks more or less in seasoning, and thus tends to warp,—the dense, slow-drying heartwood shrinking more unequally than sapwood, and resinous Conifer wood more gradually than that of broad-leaved trees. But the specific weight of wood gives no indication of its liability to shrink or warp. Conifer wood that is very resinous, and wood that has been steamed, are least liable to warp. Lime, Beech, Hornbeam, Elm, Chestnut, Birch, and Alder shrink most, and pedunculate Oak and Conifers least. Shrinkage is least longitudinally (being only nominal), greater radially (about 6 per cent), and greatest tangentially (about 10 per cent); and it is this want of uniformity in the rate of shrinkage in different directions that occasions warping, cracking, and splitting. The more rapid the shrinkage, the greater the tendency to warp, crack, and split; hence summer-felled timber is more likely than winter-felled to do so, and barked logs crack and split more than those left with bark on (which in Conifers would lead to bark-beetles breeding in large numbers). Practically, in proportion as wood shrinks in seasoning, it swells or expands again by absorbing water in a damp state of the air; and this must be allowed for in construction with timber.

4. DEFECTS IN TIMBER are due to abnormal anatomic structure and other conditions, and include *branch-knots*, *twisted fibre*, *wound-surfaces*, and *rind-galls* completely covered, and *shakes* of various kinds (*simple* or *star-shaped heart-shakes*, *frost cracks*, *cup- or ring-shakes*), which all weaken its strength, and therefore depreciate the value of timber for technical purposes. Frost-ribs being mostly full of water, are called “water-shakes” by timber-merchants. *Branch-knots* are commonest in shade-enduring trees, which do not readily lose their side-branches.

Knots in Conifers become saturated with resin, and then (especially in Larch) are very hard to plane, though they enhance the ornamental appearance of the wood. *Twisted fibre* is commonest in Chestnut, Oak, Elm, Beech, Sycamore, and Scots Pine, and makes wood more liable to warp.

5. UNSOUNDNESS is due to fungus disease. The chief kinds of unsoundness are *canker*, *red-rot*, *white-rot*, *white-piping* (Oak), and *blueing* of Conifers (especially Scots Pine); but *root-rot*, *branch-rot*, and *stem-rot* are common in old trees growing on unsuitable or imperfectly drained land. And even after it is converted and used in construction, timber, especially if only partially seasoned or in a damp place, is liable to be attacked by *dry-rot* (due to *Merulius lacrymans*) and other saprophytic fungi.

The chief fungi causing unsoundness are as follows (see also Part III., chap. iii.) :—

Canker : *Peziza* (Larch); *Nectria* (Ash and Beech mostly); *Æcidium elatinum* (Silver Fir); *Cronartium* (*Peridermium Pini*: Scots Pine).

Red-rot, from decomposition of cellulose : *Trametes Pini* (Scots Pine), *Fomes annosus* (Pine, Spruce, Silver Fir); *Polyporus sulphureus* (Oak and Birch chiefly); *P. betulinus* (Birch).

White-rot, from decomposition of lignin : *Agaricus melleus* (all kinds of trees); *Fomes igniarius* (Oak and Willows mostly); *P. fomentarius* (Beech, Oak, Elm); *Polyporus dryadeus* (Oak); *Hydnum diversidens* (Oak, Beech).

White-piping is caused by *Stereum hirsutum* (Oak).

Blueing of Conifer timber : *Ceratostoma piliferum*.

V. **The Mechanical Properties of Timber** are of the first importance, as they govern its relation to external influences. They include *strength*, *elasticity*, *flexibility*, *toughness*, *fissibility*, *hardness*, and *durability*.

1. **STRENGTH** in timber is the resistance offered to any force tending to separate its fibres, whether applied longitudinally as if pulling the fibres apart (*tension*), or pressing them together (*crushing*), or at right angles to the grain (*transverse-pressure* or *breaking-strain*), or so as to twist the fibres (*torsion*), or more

or less parallel to the grain so as to displace and separate the fibres sideways (*shearing*). The *breaking-strain* is by far the most important in timber used for construction. Of our British woods, Oak, Ash, and Larch stand this pressure best; then other hardwoods; and sapwoods and very resinous Conifer timber least (though Spruce better than Silver Fir, and Silver Fir better than Scots Pine); but any defect or unsoundness weakens the strength. The coefficient of transverse strength can be obtained from the formula—

$$P = \frac{W \times L}{B \times D^2},$$

where W is the weight in pounds placed on middle of the bar which causes it to break, L the length of bar in feet, between supports, B the breadth, and D the depth in inches.

2. ELASTICITY, FLEXIBILITY, AND TOUGHNESS.—Any substance changing shape under pressure is called *pliable*, and its power of completely resuming its original shape is its *elasticity*; if it breaks readily it is called *brittle*, and if it resists change of form, *tough*. In timber, *elasticity* is proportionate to the strength; while *flexibility* and *toughness* usually increase with the amount of water, and are greater in green than in partly or wholly seasoned wood, and also much increased by steaming. Hardwoods have generally the greatest elasticity, and softwoods the greatest flexibility and toughness; while in Conifers a moderate amount of resin increases, and much resin diminishes them; but all these three properties depend on the length and straightness of the woody fibres, and are diminished by branch-knots and abnormal growth of any kind. The modulus of elasticity is found from the formula—

$$E = \frac{L^3}{B \times D^3} \times \frac{W}{d},$$

where L, B, and D are as above, and W is the weight in pounds supported at the centre of the bar and causing a deflection of

d inches. *The toughest and most flexible stool-shoots* are those of Osiers, Willows, Ash, Hazel, Birch, Chestnut, Lime, Aspen, Oak, and Elm; while *the toughest and most flexible timber* is Ash, Birch, Willow, Poplar, Robinia, Hornbeam, and Elm. Beech becomes tough and flexible when steamed.

3. **FISSIBILITY** is the ease with which wood can be split by driving in a wedge parallel to the run of its fibres, and is important in cooperage, match-making, splitting rails, &c. Fissibility is greatest in long and straight-fibred woods, and least where the fibres are short and strongly lignified; and the drier and more elastic the wood, the easier it is to split (except in Willow and Poplar, in which a wedge holds better when the wood is moist). The greater the fissibility, the more difficult it is to obtain a fine smooth surface by planing. As regards fissibility our woods are classifiable as follows:—

Easy to split: Chestnut, Robinia, Alder, Lime, and Conifers (unless very resinous).

Medium: Oak, Ash, Beech.

Difficult to split: Hornbeam, Elm, Maple and Sycamore, Birch, Willow, Poplar.

4. **HARDNESS** is the resistance offered to the penetration of another body, and is usually characteristic of heavy woods, the hardness increasing with the strength and cohesiveness of the woody fibres. The degree of hardness manifested varies with the kind of tools used in wood-working (axe, knife, plane, saw, rasp, nail, &c.), as some work parallel to the run of the fibres and others at right angles; but the following is a rough general average:—

Hard: Robinia, Maple and Sycamore, Hornbeam, pedunculate Oak.

Moderately hard: Ash, sessile Oak, Chestnut, Elm, Beech, and Birch; also resinous narrow-ringed Larch and Pine.

Soft: Conifers; Horse-Chestnut, Alder, Willow, Poplar, Lime.

Older wood is harder than younger wood in trees, and dry wood generally harder than green wood, though heavy, hard woods like Oak, Ash, Beech, Elm, Maple, and Sycamore are easier to work when still moist than when dry. The tougher the wood, the harder it is to saw, owing to the resistance offered to the teeth of the saw in tearing the fibres apart. As regards sawing, our woods may be classified thus :—

Hard to saw : Lime, Willow, Poplar.

Medium : Birch, Oak, Alder, and resinous Larch and Pine.

Easy to saw : Conifers.

As a rule, woods with a specific gravity below 0·65 when seasoned are classed as **Softwoods**, these including Aspen and other Poplars, Willows, Lime, Horse-Chestnut, Alder, and Birch (seasoned sp. gr. 0·64, though hard to cut, and often classed as a hardwood); while the others are called **Hardwoods**—Oak, Ash, Elm, Sycamore, Beech, &c.

5. **DURABILITY** means the length of time timber continues sound and serviceable; and this, of course, varies greatly according to how and where it is used. But it depends mainly on the extent to which the wood is exposed to alternating dampness and dryness, especially during the warmer months of the year; for it is then that timber-boring insects (*Anobium*, *Ptilinus*, *Lymexylon*, &c.) and saprophytic fungi (*Polyporus*, *Agaricus*, *Merulius*, &c.), which are chiefly instrumental in decomposing the woody tissues and the ligneous substances, find the most favourable conditions for feeding and breeding. The mere weight of wood gives no true indication of its durability; because the larger the quantity of albuminoid substances contained in any kind of wood, the more likely it is to be attacked by fungi and insects which feed on these; *but, for one and the same kind of wood* (whether Oak, Beech, Larch, Pine, &c.), *the heavier it is the more durable*, owing to the higher proportion of lignin and preservative substances per unit of volume. Oak and other hardwoods (except Beech) are usually much more durable than softwoods, and Larch lasts longer

than Pines or Firs; but in Conifers durability increases with resinousness. Seasoning increases it, and winter-felled timber is more durable than summer-felled. The durability can be greatly increased by artificial means. For use between wind and water, Oak, Larch, and good Pine are best, while Alder, Elm, and Beech last longest under water or as water-troughs.

As regards general durability, our woods may be classified thus:—

Most durable: Oak, Chestnut, Robinia, and resinous Larch and Pine.

Durable: Ash, Elm, steamed Beech, and Conifers with distinct heartwood (Larch, Pine, Douglas Fir, Cypresses).

Least durable: Silver Fir, Spruce; Beech, Hornbeam, Maple, Sycamore; softwoods: Birch, Alder, Lime, Horse-Chestnut, Poplars, and Willows.

The Chief Uses to which British timber is put are as follows:—

I. Hardwoods—

Oak: ship-, house-, bridge-, and waggon-building, furniture, interior decoration, railway sleepers, telegraph-post arms, cask-staves, estate work, spokewood, and pitwood. British Oak is better in quality than foreign Oak. Pedunculate Oak is harder, stronger, and more durable; but Sessile Oak grows straighter, and is softer and easier to work.

Ash: agricultural implements, coach-building, furniture, oars, shafts, walking-sticks, hurdles, pea- and bean-sticks, &c.

Beech: chair-making, tool-handles, boot-lasts, mill-rollers.

Elm: coach- and waggon-building, furniture, boat-keels, coffins.

Sycamore: mill-rollers, furniture, bobbins, clog-soles, box-making, pulley-blocks.

Maple: used similarly, but not for mill-rollers.

Hornbeam: cog-wheels, plane-boxes, tool-handles, and wherever great toughness is required.

Chestnut: furniture, parquetry, posts and rails for fencing, split-fencing.

II. Softwoods—

Birch: furniture, bobbins and turnery, barrel-staves and crates, clog-soles, heads and handles of brooms, brooms for tempering steel-plates.

Birch and Alder were formerly much used for gunpowder charcoal.

Alder : clog-soles, barrel-staves ; is well suited for use underground and in water.

Poplars : Packing-cases, framework for veneered furniture, cart-bottoms and sides, railway brake-blocks, interior boarding, wood-pulp, match-making, turnery and carving. Aspen best for matches, match-boxes, and wood-pulp.

Willows : same as Poplars ; also bread-platters, knife-boards, and cricket-bats (Red Willow).

Horse-Chestnut : carts, sides and bottoms of, cabinet-making, bobbins and turnery.

Lime : turnery and carving, framework for veneered furniture, packing-cases.

Walnut : furniture, gun-stocks, turnery, carving.

III. Conifers—

Larch : railway sleepers, boat- and bridge-building, boarding, cart-making, masts and posts of all sorts, estate-fencing, pitwood. Small wood for hop-poles, pea- and bean-sticks, &c. Like Ash, Larch can be used of all sizes, and is durable and useful for estate work.

Cypresses, Douglas Fir, and Scots Pine or "red deal" : used for same purposes as Larch, but not so durable ; Scots Pine also for ship masts and spars, telegraph-poles, scaffolding, herring-boxes, and packing-cases.

Austrian and Corsican Pine : used for similar purposes as Scots Pine, but wood coarser and less durable.

Weymouth or "Yellow Pine" is largely imported from America for house-building and other constructive purposes.

Spruce or "white deal," and Silver Fir or "White Pine" : boarding, planking, and scantling for interior work, rough furniture, masts and spars of ships, scaffolding and ladders, packing-cases, boxes, toys, cask-staves, sounding-boards for musical instruments, pitwood, wood-pulp ; is less durable than Scots Pine.

Our Chief Wood-consuming Industries use mostly the following kinds of timber :—

Ship-building.—Oak, for ribs, crooks, &c. ; Elm and Oak for keels ; Larch and Pine for planking and lining ; Larch, Pine, Spruce, and Silver Fir for masts.

House-building and Carpentry.—Mostly imported from Baltic are Scots Pine (red deal) and Spruce (white deal) ; from Rotterdam, Silver Fir (white pine) ; from America and Canada, Weymouth Pine (yellow pine), Swamp Pine (pitch pine), and others.

Pitwood.—Larch and small Oak best and most durable, but other Coni-

fers are all largely used, the most resinous being the best. Our pit-mines are at present mainly dependent on foreign supplies, and large quantities of Maritime Pine are imported from Bordeaux.

All the Conifers can be used for pit-props down to 2½ in. top-diameter, and there is a great and constant demand for pitwood, as it lasts only about 5 years on the average.

Railway Sleepers.—Oak and Larch are the most durable, but even these are now generally impregnated; in France impregnated Beech is very largely used.

Telegraph and Telephone Posts.—Larch and Scots Pine mostly used, as Scots Pine takes creosote well; Spruce is less used as not taking creosote well, though absorbing readily under the saccharine process (see p. 307).

Scaffolding, &c.—Larch, Pine, Spruce, and Silver Fir mostly used, but chiefly imported wood.

Furniture and Cabinet-Making.—Most of our hardwoods of large size. Beech (steamed), Oak, Ash, Elm, Sycamore, Birch.

Coach-building and Agricultural Implements, Waggons, &c.—Ash, Oak, and Elm chiefly, with softwoods for waggon-bottoms and sides.

Cask- and Barrel-makers use mostly Oak, Chestnut, Birch, Elm, and Pine, with Hazel, Chestnut, Birch, and Willow as withes for cheap barrels.

Clog-makers use mostly Alder and Birch, also Willow and Poplar.

Estate Work.—Chiefly Larch, Oak, and Ash of a small size, though softwoods are also very useful for fencing, &c., *if creosoted or naphthalined.*

The Market-Value of British Timber varies greatly in different localities, and its value in the woods depends on its distance from the sawmill or from the place where it is to be used. Its value in the woods may be estimated by deducting from its market-value at the place of sale—(1) the cost of transport, and (2) about 15 to 20 per cent for the timber-merchants' profit; and of course this shows the importance of having easy lines of transport, and good roads or cheap tramways for extracting large quantities of timber.

On a rough average present prices mostly vary within the following limits per cubic foot, according to the quality and size of the timber: Oak, 1s. 3d. to 2s. 6d.; Ash, 1s. to 2s.; Elm, Beech, Chestnut, Sycamore, Maple, 9d. to 1s. 6d.; Willow, Lime, Birch, Poplar, Horse-Chestnut, 10d. to 1s. 3d.; Larch, 9d. to 1s. 2d.; Scots Pine, 6d. to 9d.; Spruce and Silver Fir, 4d. to 6d. *But please note remarks on pp. 90, 91.*

CHAPTER II.

THE HARVESTING OF WOODLAND PRODUCE, AND ITS
PREPARATION AND SALE.

HIGHWOODS allow of **thinnings** about once every 4 or 5 to 8 or 10 years, according to the kind and the age of the crop, before they mature and give their final yield in **timber**. But in addition to timber they may also yield **minor produce** in shape of *tanning-bark, tree-seeds, resin, &c.* The harvesting of coppice-growth and of timber from highwoods takes place by cutting or felling. Osier-holts are cut either with sharp knives for small rods, or with clean-cutting light billhooks. Coppices and small thinnings are cut with handbills or billhooks, while axes and saws are used for felling timber; and when stumps are removed they have to be extracted by jacks and other machines giving strong leverage.

The most effective **bills** for coppices and small thinnings are those with a well-balanced handle and fairly heavy, and the stroke is most effective when the pole can be slightly bent down with the left hand while the stroke is being delivered by the right. The cuts should be clean and slanting, and as near the ground as possible; for if the cut is ragged and splintered, rain-water lodges and the stump soon rots; while if high snags are left, the stools do not shoot well, and soon get worn out. Large poles and trees are cut either with **axe** or with **axe** and **saw**. There are various kinds of axes, differing in the shape

and weight of the head, and in the length and shape of the shaft ; but one of the most effective is the American *Kenebeck axe*, weighing altogether $5\frac{1}{2}$ to 7 lbs., with bulging cheeks to

Fig. 70.

Teeth of Two-handed Saws.

prevent jamming. For sawing, 2-handed saws (Fig. 70) from 4 to 6 ft. long are generally used, and the ease of working them depends greatly on the handles being conveniently placed and shaped. Good saws should be made of the best steel ; should have a slightly convex cutting-edge, with more or less triangular teeth ; should provide free space for removing the sawdust ; should have teeth well set to different sides, the back of the blade somewhat thinner than the face, and a weight of 5 to 6 lbs. But to prevent jamming, *wedges* have to be used.

Fig. 71.

Felling with Axe alone.

Felling with axe alone (Fig. 71) is only suitable for large poles or small trees. The stem is first cut into as low down as possible (*a*) on the side at which it is desired to fall, and the cuts should be made wedge-shaped as far as, or a little beyond, the centre of the stem. A second cleft (*b*) should then be opened out on the opposite side of the stem slightly above the cut first laid in, and this second cut is continued until the tree gradually falls over towards the other side.

Felling with axe and saw (Fig. 72) is a better way with large timber, as there is less wastage. The tree is laid in as

Fig. 72.

Felling with Axe and Saw.

before (*a b*) to about $\frac{1}{4}$ of its diameter; then the saw is applied at same level (*c*) on opposite side of the tree. As the saw cuts in, the opening it makes has to be kept open by **wedges**, to prevent jamming and help to throw the tree over. To prevent the wedges springing out, they should, especially in frosty weather, be sanded or rubbed with earth or ashes; but the safest and most powerful wedge to help in throwing over the tree is the "*Universal wedge*," made of steel (Fig. 73).

But most timber is obtained by cutting through the main roots just below the ground, and throwing the tree with lever appliances like the **common jack** (Fig. 74), or hauling it over by the far more powerful **chain-lever** or **wood-demon** (Fig. 75), consisting

Fig. 73.

of two strong iron chains, *mm*, fixed to a stout iron-ringed pole *C*, that is fastened to some stable object (like a boulder or large tree) by a mooring chain, *A*, and which acts in connection with the main chain, *B*,

attached to some lofty branch of the stem to be pulled over. By moving the pole-lever *C* alternately backwards and forwards, the hooks *mm* can gradually be moved upwards link by link along *B*, so that the top of the tree is dragged over, as the leverage is effective, though gradual. Or an arrangement of

Fig. 74.

Throwing with Common Jack.

pulleys and tackle can be used with similar effect. On marshy

Fig. 75.

The Chain-Lever or Wood-Demon.

Fig. 76.

ground additional stability can be given by mooring the chain *A* to a series of posts, as shown in Fig. 76.

Stump extraction is usual only when converting woodland into agricultural land, as it seldom pays to grub up the stumps for fuel (though it is the best safeguard against the Pine-weevil in Conifer woods). It can best be done by implements or machines which all work upon the principle of gaining great force by leverage. If the side-roots have been cut through all round, the stump can often be raised by the leverage of a long and stout pole passing through an iron ring attached to a strong hook, that can be inserted below one of the main side-roots (Fig. 77). Or a long pole can be fixed with one

Fig. 77.

Stump-extraction by hook-and-pole leverage.

end resting on the ground and the other on the top of a jack, with an iron chain binding this end of the pole to one of the stump-roots; and as the jack is wound up, the stump is partially tilted over. The *Australian monkey-jack* is another method of applying strong leverage; but one of the most powerful is the American *Hawkeye*, worked by horse-power, the machine itself being firmly moored to one or more stumps, and the extracting force being provided by strong leverage. Large stumps are also often blasted with gunpowder or dynamite, but this is not always cheaper than the use of mechanical appliances.

The **best season for felling timber** is during autumn just before the fall of the leaf, or during winter as soon as possible after the fall of the leaf, when the tree contains least sap and when there will be least evaporation and shrinkage. But if Oak or Larch is to be peeled for tanning-bark, or if oak-coppices

are to be barked, then the fall must take place in spring when the sap is beginning to flow; and for bentwood furniture summer-felled Beech is preferred for steaming. Summer-felled wood is also easier to cleave and split than winter-felled. If Conifers are left in woods after felling, they are almost certain to become infested with bark-beetles during spring, and should if possible be removed at latest by the middle of June, or else barked, leaving only narrow rings of bark at ends and middle to try and prevent cracking. *Osier-holts* are cut from January onwards, unless inundated, while *thinnings* in plantations can best be done in spring. If felling be done by the proprietor's own men, they are much more likely to be careful of his interests as regards damage to fences, other trees, and underwoods, and felling and logging to best advantage, &c., than if the timber merchant's employees do the felling and logging.

In felling timber the main points to be kept in view are:—

1. *All trees to be felled should be plainly blazed and hammer-marked both on stem and root.*
2. *Trees should be felled so as to give the largest possible out-turn in timber, all large trees being felled by axe and saw.*
3. *Trees should be felled so as to do the least damage to other trees, underwood, fences, or themselves. Lopping the branches is often desirable. On hillsides it is usually best to let the tree fall slantingly uphill, because the crash is then least, and the log can generally be removed easier.*
4. *Trees should be felled in the direction from which their removal is easiest, unless unnecessary damage would thereby be done.*
5. *Timber felled should be at once cross-cut by saw into the best size of logs, and removed to the nearest road or ride, and more trees should not be at any time felled and left on the ground than can be conveniently dragged out within the next two or three days.*
6. *On reaching the road, the smaller classes of wood from thinnings (poles) should be at once assorted according to their size and class for sale or other disposal.*
7. *Trees to be barked should be stripped immediately after felling, and before the logs are dragged out to the road.*
8. *Felling operations should be temporarily suspended during high wind, to avoid accidents, and because of the uncertainty of making the tree fall in the desired direction.*
9. *Large trees and poles over about 9 in. diameter at base should, as a rule, be felled by axe and saw; while small poles and coppice-growth should be smoothly and slantingly cut by bill or by axe, according to their size, to prevent water lodging and rotting the stools, and to stimulate shoot-production.*

The cost of cutting and sorting coppices of 12 to 16 years' growth varies from about 10s. to 15s. per acre according to the thickness of the crop; while the cost of felling, trimming, and logging timber is about 1s. 6d. to 2s. 6d. per load of 50 cubic ft. for Conifers and softwoods; 2s. to 3s. for most hardwoods; and 2s. 6d. to 3s. 6d. for Oak and Ash.

When felled and logged, the logs should be marked serially, while poles and branch-wood should be assorted according to length and size, the smaller stuff stacked in cords for fuel, and the brushwood faggoted. The marking of trees and logs can best be done with a revolving numbering-hammer (Fig. 78).

Fig. 78.

Revolving Numbering-Hammer.

Storage-depôts have to be formed at convenient places when felled timber cannot be at once removed from the woods. Here the logs should, so far as practicable, be raised above ground on poles or billets of wood, to assist seasoning and prevent damp-rot, and due precautions being used (*e.g.*, barking Conifer logs) to prevent such depôts becoming breeding-places for noxious insects.

In Britain timber is sold by **public auction**, by **tender**, or by **private contract**; and it may be sold either **standing** or **felled**. Where practicable, it is usually best to sell it standing, at fixed rates per cubic ft. for 1st class and 2nd class dimensions (also to be fixed), with a reasonable deduction in case of unsoundness, the **cubic contents** of the logs being measured by multiplying the length in feet by the *square of mean quarter-girth*

(free of bark) in inches, and dividing by 144 (see also page 89). If timber be felled before selling, the timber merchant knows well that the landowner is practically forced to sell, even if he does not get a fair market-price for it, unless he can convert it at a saw-mill of his own. Theoretically, felling, logging, and assorting by the landowner's own men, and sale by public auction, would be the best means of disposal, unless in districts where rings are formed by timber merchants to keep down prices locally.

When sales are made by private contract or tender, the conditions should stipulate the *mode and time of payment*, the *date by which timber should be removed* (before 31st May if possible), the *route of extraction*, the *breadth of the cart-wheels* to be used (not less than 4 in. flange), and what *payment is to be made for damage* done by the buyer's workmen, and also making provisions in case of the buyer failing to satisfy all his covenants. As a rule, such sale-contracts are usually drawn up by the landowner's agent, and revised by his solicitor.

Coppices are usually sold standing, either privately or by auction, at so much per rood or acre, to be cleared by a fixed date, up to end of March for ordinary coppices, and up to middle or end of May for oak-bark coppices, and poles to be reserved as standards should be marked with a ring of white-wash or paint about 5 ft. up. The poles cut are classed according to size and sold as hop-poles, &c., according to local demand and custom, by the dozen or 100. Smaller stuff is used for hurdle-making, crate-wood, hurdle-hoops, bean- and pea-sticks, stakes, thatching-rods, &c., and what is then left is faggoted in bundles 3 ft. long and 24 in. girth for fuel. *Alder and Birch* coppices are saleable for clog-making when yielding stems 4 in. to 5 in. or more in diameter. **Hurdlemaking** with Hazel, Ash, Chestnut, Birch, and Willow, is now almost a lost art; and the market for all kinds of coppice-material, including Oak-bark, is so low that coppices hardly pay, and many of them

are being converted into highwoods. **Osier-holts**, cut over from January onwards when the land is not inundated, yield *green rods*, fresh and unpeeled, *brown rods*, drying in skins, which later on are put with the cut ends in water and then peeled to form *white rods*; but if brown rods are boiled for peeling, then they become *buff* in colour. **Oak-Barking** is no longer so usual or so profitable as formerly, although Oak and Larch are still peeled, and the bark sold for tanning. The largest amount of *tannic acid* is contained in smooth or silver bark of 14- to 16-year-old Oak-coppices (giving 15 to 20 per cent tannin when seasoned), while seconds, or medium quality bark from poles and branches beginning to fissure, give 10 to 15 per cent, clean bark from older stems 8 to 10 per cent, and coarse rough bark only 5 to 8 per cent. Sessile Oak has thicker bark and more tannin than Pedunculate Oak; but the amount of tannin depends greatly on the quality of the soil and the situation, warm exposures producing the most and the thickest and best bark. Alder contains 16 to 20 per cent, but is not used, as it blackens the leather. *Larch-bark* contains 10 to 15 per cent tannin, *Spruce-bark* about 8 per cent, *Silver Fir* 5 to 6 per cent, while *Willows* have 5 to 7 per cent (used for Russian leather), and *Osier-bark* 8 to 13 per cent (used for glove leather).

The **best time for bark-stripping** is during warm, damp weather, when the young leaves are just flushing; and the bark peels better in the morning or evening than in the daytime. The later the stripping is delayed after the sap begins to flow, the less is the amount of tannin contained in the bark.

In copse with standards the underwood is felled and the Oak-bark stripped first, before the standard Oak-trees are felled and barked. The coppice-rods are lightly beaten with a wooden mallet against a smooth stone, when the bark can easily be loosened; but trees have to be felled, marked off in sections of $2\frac{1}{2}$ or 3 ft., and bark loosened with a barking-iron, the mallet being used as little as possible, because malleting means injury

and loss of tannin. Poles are barked across a pair of forked stakes. *The drying of bark* takes place on stages formed of small poles or rods laid upon cross-rods supported by Y-shaped stakes, the bark being laid on the stage rough side uppermost to protect it from rain. The stages are erected in a dry, open, warm spot, and the bark should be turned every few days, putting the sappiest pieces on top. In fine weather the bark seasons in 8 to 10 days; but drying may take about a fortnight or more in dull damp weather, when it should be handled as little as possible, as it then turns mouldy. The *seasoning* is complete when the bark becomes so hard and dry as to snap when bent. The quicker the seasoning, the better the quality of the bark. The best quality is creamy light-brown; if dark-brown, owing to damp weather, the quality is not so good. Mouldy pieces should be scraped clean, and the mouldy parts burned; and badly damaged pieces should be burned to prevent the mould-fungus spreading. The *seasoned bark* has then to be chipped into small pieces about 3 in. square, and put into large bags for transport.

Park and hedgerow trees yield from 6 to 10 cwt. of seasoned bark per 50 cubic ft. of timber. In drying the bark loses over a third of its weight when green.

The barking of large Oaks, including curing, usually costs from 30s. to 40s. per ton, and chipping and bundling 8s. to 9s., while the present selling price is only 50s. to 55s. per ton (*of 21 cwt.*) delivered at the nearest railway station. There is therefore very little profit now in barking large Oaks, while the market for Coppice-Oak is also very poor; so that in many cases winter-felling of coppices, standards, and park and hedgerow timber is preferable.

Larch, Spruce, and Birch can be stripped, chipped, and bagged for about $\frac{2}{3}$ of what Oak-bark costs, but the selling price is only about $\frac{1}{2}$ that of Oak-bark.

Tree-Seeds should be collected soon after they ripen, mostly

in autumn, though Elm-seed should be gathered (and sown) when it ripens in June, Birch in July and August, and Silver Fir cones before they fall to pieces in October. Oak, Beech, and other hardwoods should be collected in autumn and stored over winter; and though most Conifers only open their cones when dry east winds come in spring, yet it is best (especially

Fig. 79.

Seed-kiln for extracting Scots Pine seeds from the cones.

a. Furnace.	d. Passage.
b. Heating-pipes.	e. Cooling-chambers.
c. Shelves with trays for cones.	f. Outlets for hot air.

where there are squirrels) to collect the cones of Pine, Spruce, and Larch in autumn. All tree-seeds kept over winter should be stored in a dry, airy place, and turned over from time to time to prevent their heating. Pine and Spruce cones can be opened when wanted in spring by spreading them out in the sun and turning them over frequently; but where a considerable quantity is being handled, it is usually treated in a seed-kiln (Fig. 79) by being

warmed to a temperature of about 100° - 110° , the seed being then allowed to fall down into a cooling-chamber. Larch cones, however, being very resinous, have, after being warmed, to be broken into pieces in revolving drums. All Conifer seeds have to be cleaned by removing their wings before sowing, which reduces their weight and bulk considerably (10 lbs. winged seeds of Scots Pine give 7 lbs. clean seed, and of Larch 8 lbs.)

CHAPTER III.

TIMBER-TRANSPORT BY LAND AND WATER.

1. **Transport in Woodlands and on Roads.** — After logs are dragged from the interior of woods to the rides or the roads by horses, they have to be carted on 4-wheeled **timber-waggons** or a 2-wheeled *timber-bob* or *janker*, or conveyed by a tramway to some central depôt, sawmill, railway-station, wharf, &c. ; and sometimes a *traction-engine* is used for heavy road-traffic. **Dragging** is mostly done by horses in Britain, but on the Continent oxen are largely employed. The dragging of heavy logs can be facilitated by the use of a *dragging-shoe* slipping below the end of the log, or by raising the logs fore and aft on little sledges.

The common *timber-waggon* has 4 broad-flanged wheels, the hind pair being adjustable according to the length of the log, which is fixed by chains to the long pole forming the beam of the cart, and levered up high enough to swing clear of the ground. The *timber-bob* or *janker* consists of two broad-flanged wheels with a curved iron axle, upon the top of which rests a strong iron-shod shaft ending in a strong iron hook. This is brought into position over a log round which an iron chain has been loosely put near its centre of gravity ; and on the tip of the shaft being elevated and the hook at the other end slipped under the chain, the log is raised to swing clear of the ground by the tip of the shaft being pulled down again and the end of

log fastened to the shaft. It saves time and trouble, however, if in place of putting a chain round the log a strong pair of iron clips be used. The wheels of timber-carts should be at least 4 in., and preferably more, in the flange, otherwise heavy loads cut up soft roads badly.

The cost of carting varies greatly according to kind of wood, distance, gradient, general condition of road, and state of weather, and may amount to from $\frac{1}{2}$ d. to $1\frac{1}{2}$ d. per cubic ft. and per mile up to 4 to 6 miles, and about $\frac{1}{4}$ d. to $\frac{1}{2}$ d. per cubic ft. and per mile beyond that.

Tramways are only cheaper than carting when the *land is*

Fig. 80.

level or slightly downhill and the *gradient slight*; and wherever there is a good network of metalled roads, carting is generally the cheaper, unless the quantity of timber be large. The use of a traction-engine and goods-waggon is economical where long distances have to be covered along good roads, and especially if the timber can be converted at a sawmill in or near the woods before transport. For forest tramways the best gauge is 24 in. (Fig. 80), and the iron sleepers are usually 3 ft. from centre to centre, the whole, including rails, being in 15 ft. lengths, so as to be easily carried by two men when it needs to be shifted. A forest tramway worked by horses operates regularly in Beaumont Forest, Roxburgh; and in the Canonbie

and Langholm woods, Dumfriesshire, a light tramway worked by men is found a good and economical way of extracting timber from narrow, winding gulleys down which there are no roads.

Railway transport in Britain is regulated by the general railway classification of goods, which prescribes the method of measurement and classifies the rates payable for different kinds of timber.

Sledging of poles and logs might in Britain be done far more extensively than is yet the case. On the Continent sledges are drawn by woodmen, horses, mules, or oxen. The sledging-track is corduroyed with small poles cut into cross-pieces, and poles are placed longways along the outer edge to keep the sledge from slipping over any hillside or running off the track. The cross-pieces must be close enough to allow the sledge always to rest on two of them throughout its whole descent; and where woodmen drag the sleds, these cross-pieces should not be more than 2 ft. apart to give the men a good foothold. Small hand-sleds are used for fuel and large sledges for timber, all being formed of two horizontal *runners* (often shod with iron), cross-binders joined to the runners, and a strong hooked iron brake or drag to regulate the speed. For hand-sledding the tracks are made 4 to 6 ft. broad, with a constant gradient of from 1 in 14 up to even 1 in 4 (or 7 to 25 per cent). The large timber-sledges drawn by horses, mules, or oxen consist of a front sled and a hind sled, to raise the logs off the ground and diminish friction. Both dragging and sledging are easiest on snow and in wet weather.

Sliding and shooting of timber are simple methods of extraction largely practised in the mountainous woodlands of Central Europe, and especially where the timber-slide can be made to end at some point favourable for further transport (in log or after conversion) by river, rail, or road. Timber-slides of various kinds can be constructed on roadways or else

entirely of woodwork ; but in either case the chief points are (1) the preparation of a *good bed* down which the timber can glide with least friction, and (2) the provision of *safeguards* to prevent the logs or fuel-billets springing out of the slide.

Roadway timber-slides are mostly used for extracting Conifer logs in large quantities when the pathways and side-roads in mountain tracts have been so projected as to provide large sweeping curves, round which long logs can glide easily. The slides are usually made from 5 to 8 ft. broad, with corduroy cross-pieces consisting of round or split poles laid smooth-side uppermost, and fenced in along the outer edge with poles laid lengthways to act as flange-like side-guards. For winter-sliding when snow covers the ground a gradient of from 1 in $12\frac{1}{2}$ to 1 in 8 (or 8 to $12\frac{1}{2}$ per cent) is needed, and for summer-sliding from 1 in 8 to 1 in $5\frac{1}{2}$ (or $12\frac{1}{2}$ to 17 per cent) ; but in either case the steepest gradient should be at the top, for starting the logs in their descent, and the lowest gradient at the bottom end, where the slide terminates. Such roadways can also be used for sledging, with cross-pieces close enough to allow the sledge to rest always on two. And they are economical, as 100 to 120 logs can daily be shot down a slide over $1\frac{1}{4}$ mile long. In laying out such a slide, sharp turns and sudden changes of direction have to be avoided ; but where unavoidable, a buffer is made with billets of pole-wood, and when a log in coming down bumps against this, it rolls over into the track below and slowly continues its way in the new direction—with assistance, if necessary (Fig. 81). The logs are launched into the slide thick end first, and to make them glide easily the butts are rounded with an adze. To prevent accidents the launching of each log is announced by bugle-call ; and no other log is despatched till the arrival of the previous one is similarly announced from below. When all the timber has been slid down, the slide itself is broken up and extracted in the same way.

Wooden timber-shoots are made with 6 or 8 poles of from 4- to 12-inch diameter arranged more or less semicircularly, two forming the base and two or three being ranged on each side to form a trough varying from about $2\frac{1}{2}$ to 5 ft. in breadth. The two bottom poles rest on the ground so far as possible; otherwise wooden trestles are built up for the shoot to rest on, so as to maintain the necessary gradient. In central Europe, fuel-billets, short log sections, and long logs are all thus extracted in mountain tracts; and of course the solidity of con-

Fig. 81.

Turning-Point and Buffer on a Roadway Timber-Slide.

struction varies considerably in such cases. Where the gradient is below 1 in 16 or 17 (6 per cent) long logs can only, without snow on ground, be shot down during frosty weather, when men are kept watering the shoot to make it an ice-slide. For ordinary winter-sliding when snow is on the ground a gradient of 1 in 33 to 1 in 17 (3 to 6 per cent) carries long logs, while 1 in 16 to 1 in $8\frac{1}{2}$ (6 to 12 per cent) is needed for small log-sections and fuel-billets. For dry-sliding of long logs in summer the gradient has to be 1 in $5\frac{1}{2}$ or 5 (17 to 20 per cent), while small logs and fuel-billets need from 1 in 5 to 1 in $2\frac{1}{2}$

(20 to 40 per cent). With too low a gradient such wooden slides are useless; and with too high a gradient the velocity of the logs may cause them to spring out of the shoot. Hence, wherever a dangerous velocity is likely to be acquired, a brake can be formed by fixing two stout poles of equal length and girth firmly at their thinner upper ends well above the slide

Fig. 82.

A Brake or Check on a Wooden Timber-Slide.

and letting their thicker lower ends hang loosely on the base of the slide (Fig. 82), and as a log raises them, and passes through between them, the strong friction reduces the speed. Such wooden shoots cost far more to make and maintain than roadway timber-slides, and do not last so long, their average life being about 7 years; and even then the logs used in making them get so battered as only to be fit for fuel.

Flumes or Water-shoots (Fig. 83) are broad V-shaped water-

tight troughs, much used in California for rapid transport of logs over long distances in mountain tracts. They have to be carefully laid at a constant low gradient, and have to cross gullies sometimes over 200 ft. deep; and a speed of 2 to 3 miles per hour is attained with a fall of only 1 in 200, while 1 in 100 increases it to from 6-9 miles an hour, and 1 in 20 to over 20 miles an hour. On some of the American flumes distances of over 40 miles are covered in less than 4 hours. Such shoots can only be made where a good and constant water-supply is assured. The angle of the V has to be filled with a triangular piece of wood to form a flat base, else logs may get jammed in the trough.

Fig. 83.

A Flume or Water-Shoot.

2. Transport on Inland Waters can take place by loose drifting or floating in rafts. Timber-floating is customary in Strathspey;

but many of our inland waterways might be much more utilised thus, as all of our Conifers and most of our broad-leaved trees are floatable, and water-transport is cheapest. The **drifting** of single logs, sleeper-pieces, &c., can be begun anywhere, merely by launching them into the bed of a stream, breaking up any obstruction that forms on the way down, relaunching stranded logs, and collecting them at some depôt lower down; but **rafting** can only begin at some convenient depôt, such as land at the junction of two streams, or where a road or a timber-slide ends. **Loose drifting** is cheapest, but there is more risk of jamming and waterlogging, the average loss varying up to 5 per cent, and sometimes more. A fall of 1 to 2 per cent, a depth of 2 to 3 ft. of water, and a minimum

breadth of 2 to 3 ft. more than the length of the longest logs drifted are necessary; and the stream-banks have to be specially prepared at unfavourable places, while water has to be stored in reservoirs for flushing, unless spates can frequently be utilised. The **rafting** of long, large conifer logs can also be done with a depth of 2 to 3 ft. of water, while the breadth of the clear waterway need only be sufficient to let the first sections of the raft pass easily; but the bed must be prepared so as to be without sharp bends, and to be clear of boulders, and any soft banks must be sloped off to prevent erosion.

Fig. 84.

Brake on end-section of raft, dragging on bed of floating-stream.

In the Black Forest, where rafting has reached its greatest development, the first section of a raft consists of 4 light logs lashed together with twisted withes and with

a movable guiding-prow in front, worked vertically by a pole-lever; and the following sections are each formed of from 5 to 10 logs according to the breadth of the stream, the top-ends being at front and the outer logs being loose at their thick end to afford free play in rounding corners, while the middle sections (which are always the widest) sometimes actually exceed the breadth of the stream. The tail of the raft consists of logs lashed together only in front, and in the middle of the last firm section a pole-brake (Fig. 84) is arranged to drag along the bed of stream and prevent the end of the raft from moving more rapidly than the front. Rafts there consist of from 300 to 500 logs, in from 50 to 70 sections averaging 7 logs per section. The loss in rafting is only nominal.

CHAPTER IV.

THE SEASONING AND PRESERVATION OF TIMBER.

THE larger the proportion of nitrogenous or albuminoid substances contained in any kind of wood, the more likely it is to be attacked by insects and saprophytic fungi, which are the chief causes of decay, and whose attacks are facilitated when timber is exposed to rapid alternation of dampness and dryness, especially if combined with warmth. If the albumen can be sterilised or so altered as to be made unfit for the food of insects and fungi, the woody fibres then become strongly protected against both of these destructive agencies, and also against the action, thus obviated, of dissolving ferments developing under their operation. Some kinds of timber, and notably hardwoods as compared with softwoods, and very resinous as compared with only slightly resinous Conifers, have more or less of natural protection from substances contained in their tissue (*e.g.*, tannic acid in Oak, strong resinification in Larch and Pine, &c.); but all timber is much more durable if utilised in dry and airy places, or if entirely submerged in water, or buried in the ground where atmospheric oxygen is cut off and there are practically no alternating changes from wet to dry. The weight of a piece of wood gives of itself no reliable indication of its durability—*e.g.*, Beech used, say, for fencing decays much sooner than Larch; but for any one particular kind of wood (Oak, Ash, Beech, Larch, Pine, Spruce, &c.), the

higher the specific gravity, the more durable the timber, because that means a larger proportion of woody fibres, and of lignin, tannic acid, resin, and other substances preservative of the woody tissue. Speaking generally, wood felled in autumn, just about the fall of the leaf, when there is least sap in the tree, is more durable than that cut at any other time of the year; and wood felled just before the flush of the foliage in spring, when the tree is fullest of sap, is usually least durable.

The preservation of timber may take place—I. *By seasoning*—1, *naturally*, by gradual drying in the open air; or 2, *artificially*, by evaporating the sap in hot-air chambers, or by steaming it in hermetically closed boxes or cylinders (with or without superpressure); and

II. *By impregnation with antiseptic substances*—1, through *simple immersion*, or 2, through *injection under pressure*. Mere superficial coating with paint, &c., is of little use unless the wood be thoroughly seasoned, and is to be used indoors. But by far the most effective way of increasing durability is to impregnate the woody tissue as thoroughly as possible with antiseptic fluids, rendering the albuminoid substances unfit for the food of insects and fungi.

1. **Seasoning naturally.**—The specific gravity of timber is much greater when the wood is green than when most of the sap has been evaporated, and the timber has become air-dried or seasoned. And though hardwoods generally lose about 30, Conifers about 40, and softwoods about 45 per cent of their total weight during the long, slow process of seasoning in the open air, yet they all still contain on the average from 8 to 12 per cent of moisture, which can only be got rid of by drying artificially in closed chambers.

The best method of seasoning broad-leaved trees having a distinct heartwood is to girdle or ring them by cutting clean through the bark and sapwood and into the inert heartwood all round the stem, just above the buttresses near the ground.

This arrests the upward progress of sap from the roots; and when all the sap that was in the tree at time of girdling becomes evaporated through the foliage, the leaves die, and gradually (within about two years at most) the twigs, and the small branches, and the bark are shed; while the tree gradually becomes seasoned and less likely to warp or shrink after conversion, and also lighter in weight and rendered more floatable and less heavy to transport. Conifers cannot, however, be safely girdled, as they at once become infested with bark-beetles, and the best way of seasoning them is to bark them as soon as felled, leaving only narrow rings at both ends to prevent them splitting and getting long deep cracks. Wood in the round usually takes from two to four years to season if barked, and longer if unbarked; while for hardwood planks about a year is allowed for each inch of thickness before seasoning is complete. But seasoning is much more rapid if the wood has been previously floated or soaked in running water for some time to remove some of the sap by dissolving it. Of course, light porous wood seasons sooner than heavy dense wood, and sawn or split wood seasons sooner than wood in the log. Unless well raised off the ground, wood will not season thoroughly. If boards fresh from the saw-bench be set on end, this helps the seasoning of some kinds of wood (*e.g.*, Beech).

2. **Seasoning artificially** may take place either by evaporating the sap in properly ventilated hot-air chambers, or by steaming it in closed cylinders.

In **seasoning by hot air** the converted wood is ranged so that the air can circulate freely between the pieces; and the dry superheated air, warmed either by steam-pipes or hot-air tubes, is kept in circulation by large revolving fans, while ventilation is provided by circulating vanes and cowls. Whatever the size of the drying-chamber, about one-third is filled with wood and two-thirds with the hot air. Drying should only take place at a temperature not above 110° to 140° Fahr., though 95° to

105° is usually sufficient. The damper the wood, the slower should the rate of seasoning be, as rapid heating makes the planks warp and split. There should not be too much ventilation; it is sufficient if the air be renewed once every five minutes. But this depends mainly on the dampness of the air, as in very dry air the evaporation of the sap proceeds so quickly that the wood may easily become split and cracked. After drying, the wood should still contain about 10 to 12 per cent of water, for if thoroughly dried it is brittle, difficult to work, absorbs moisture rapidly, and is then apt to warp. The time taken to season wood depends on the kind, and on its shape, size, and moistness. For thin boards and planks about 3 to 5 days suffice, while from 8 to 10 are needed for larger wood. Another method is Haskin's *Vulcanisation* process of rapidly seasoning converted timber by hermetically sealing it in powerful iron cylinders and exposing it under a pressure of about 13½ atmospheres (200 lbs. per square inch) to the influence of air (dry?) superheated to between 200° to 300° Fahr., the precise temperature being the secret of the process (probably a little over boiling-point, 212°). The time taken depends on the size of the timber; for sleepers 8 hours suffice.

In **steaming**, the converted timber is usually put into a thick wooden box 10 to 12 ft. long and 5 to 7 ft. broad and high, bound with iron and hermetically closed, the box resting slantingly on strong supports, so that the condensed water can be run off at the lowest part by a turncock, while the mouth of the steam-pipe enters at the opposite end. To economise steam, the wood is packed closely into the box, but the boards are set on edge so that their surfaces should come into contact as little as possible. When steaming is begun, the condensed water runs off fairly clear, but later on it gets much discoloured and smells strongly of the extracts dissolved; but the steaming is continued until the condensed water again runs clear and colourless, showing that the sap has been fully dissolved and

withdrawn. Steaming takes from about 40 to 80 hours, according to the size of the wood, and generally makes the colour darker than wood naturally seasoned. Oak turns dark-brown and Maple reddish, while Beech turns brown to pinkish and is then preferred for parquet-work. Steamed wood dries quicker, is lighter, and is less liable to warp and split than unsteamed wood of the same degree of dryness. While still warm and moist as it comes from the steaming-box, it is very flexible; and in cooling and drying it retains the form given to it while still warm and moist. This quality is made use of in bending wood for ship's planking, carriage- and waggon-making, cooperage, chair-making, &c.

II. Impregnation with Antiseptics.—The earliest methods of preservation by antiseptic means were simple submersion of converted wood in sea-water, or in a solution of common salt, or in milk of lime (a 1-in-40 solution of slaked lime in water), or by charring and coal-tarring fence-posts and stobs at the lower ends put near or below the surface of the ground. The *ideal preservative fluid* would be one that preserves thoroughly, penetrates easily and deeply into the wood, remains there permanently, is cheap and innocuous, and does not increase the inflammability of the wood; but no such impregnating substance has yet been discovered. For large timber the four oldest antiseptic processes worked on any large scale are—

1. *Kyan's method* (1832), by simple immersion and imbibition of a 1-per-cent solution of *corrosive sublimate* (bichloride of mercury), 1 lb. dissolved in 10 gals. of water (100 lbs.) being sufficient to impregnate 50 cubic feet of well-seasoned timber;

2. *Burnett's method* (1838), by injecting a 2- to 3-per-cent *chloride of zinc* solution under pneumatic pressure of 105 lbs. per square inch ($7\frac{1}{2}$ atmospheres) at 230° F., the wood operated on (chiefly for railway sleepers) being thoroughly seasoned;

3. *Bethell's method* (1838), by injecting *creosote* (crude heavy oil of coal-tar) into thoroughly seasoned wood under a pressure

of 140 lbs. per square inch and at a temperature of 120° F.; and

4. *Boucherie's method* (1840), by injecting a 1-per-cent solution of *sulphate of copper* (blue vitriol) under a pressure of 14 to 28 lbs. per square inch by means of a guttapercha tube conveying the solution from a tank 30 to 33 ft. overhead into a narrow chamber formed by a cap fitting over one end of the log, so as to force out the sap from the other free end as the solution presses its way in—a process which is easier in the case of green than of seasoned wood.

The *corrosive sublimate* method preserves well, but is dear and poisonous, corroding iron and causing sores on workmen's hands, and soon dissolving out in wet places. *Chloride of zinc* is a weak antiseptic, and is easily soluble, but soon gets washed out. *Creosote* is nearly as strong an antiseptic as corrosive sublimate, and is not poisonous; but it is dear, pungent in odour, and greatly increases the inflammability of wood treated; it is therefore only suitable for timber used in the open air, and not for house-building timber and pitwood. *Sulphate of copper* is a weak antiseptic and corrodes iron, but is the cheapest process. Impregnating with *creosote*, originally introduced by Bethell in 1838, with pneumatic pressure, is now the chief British method. The commercial creosote used is the crude heavy oil of tar obtained by dry distillation of coal-tar (and not the true creosote got by dry distillation of wood-tar). Its action is threefold, as it (1) clogs up all pores in the wood, and so keeps out air; (2) coagulates the albumen; and (3) acts as a poison to insects and fungi. Barium salts are also good, cheap antiseptics.

Creosoting with heavy coal-tar oil (boiling-point 365° F.) may either take place by simple immersion in open iron tanks, or by injection under pressure in closed iron cylinders. The simplest and cheapest way to treat small quantities of well-seasoned wood (such as fence-posts, &c.) is by immersion, and to pack it (after being warmed, if convenient) into the open tank, and fill

this with creosote and heat it to a little over 212° F. (to evaporate the water still in the wood); then keep it at that heat for about 24 hours (or more, according to size of wood), run off the hot oil, and take out the creosoted wood when cool enough to handle. For such purposes, an open oblong iron tank or boiler and a furnace cost about £60. Beech and Scots Pine absorb the oil most readily, and Spruce and Larch least readily; while softwoods and Conifers generally absorb more readily than hardwoods. Scots Pine and softwoods take easily about 8 to 9 lbs., and even up to 10 to 11 lbs. (1 gallon) of creosote per square foot; but neither Oak nor Larch, the most durable woods without treatment, absorb the oil well. Creosoted Beech fence-stobs last twenty years, while untreated Beech only lasts about three years. In the case of Scots Pine stobs, long immersion is a waste of creosote, as it runs out again on the stobs being stacked after treatment. As absorption is not uniform, the cost of creosoting varies both with the kind and the quality of the wood; but with creosote at $2\frac{3}{4}$ d. a gallon, creosoting on the average usually comes to about 4d. per cubic foot, or 1d. per fence-stob $4\frac{1}{2}$ ft. $\times$ 3 in. $\times$ 3 in., and 9d. per 100 lineal foot of paling rails 4×1 in. (though ranging up to 6d. and 1s. 3d. respectively).

When creosoting large quantities of wood, railway sleepers, &c., in closed iron cylinders with injection under pressure, the timber is packed as closely as possible, the air extracted by an air-pump, and creosote heated to 120° F. run in; and when full, a force-pump is used to gradually produce whatever pressure is desired (usually 100 to 120 lb., but sometimes more), until a gauge attached to the creosote tank shows that absorption has ceased. Softwoods can thus be made to absorb 10 to 12 lbs. of oil per cubic foot. At Welbeck a pressure-cylinder 30 ft. long by $4\frac{2}{3}$ ft. diameter with self-contained pumps, which cost about £300 and is worked by a $2\frac{1}{2}$ horse-power portable engine, takes a charge of 450 cubic feet of small converted timber (gates,

fence-posts, &c.) that can be subjected to a pressure of 100 lbs. per square inch in about three hours. On absorption under that pressure ceasing, the door is unscrewed and the superfluous creosote run off, and the timber is taken out next day. When creosoting is done thus on a large scale, the total cost comes to about 3d. to 4d. a cubic foot, varying of course with the price of creosote. On the average, $2\frac{1}{2}$ gallons or $27\frac{1}{2}$ lbs. of creosote are considered enough for Scots Pine sleepers 9 ft. $\times$ 10 in. $\times$ 5 in. = $3\frac{1}{8}$ cubic feet, or $8\frac{4}{5}$ lbs. per cubic foot; while when Oak sleepers are treated, the specification varies from 4 to 6 lbs. per cubic foot.

On the Continent one of *Rueping's creosoting processes* is to first subject the wood to a pressure of 60 to 65 lbs. in order to compress the air into the interior cells; and on warm creosote being run into the cylinder, the pressure is increased to 105 to 225 lbs. according to the size and the quality of the timber; and under this high pressure any creosote not adhering to the cell-walls is forced out again and run off, thus effecting a saving in creosote, while giving a more thorough impregnation. *Another of Rueping's processes* now much used for sterilising sleepers on the Continent, is impregnation with an *emulsion of creosote and resin soap*, as it has been found to penetrate the wood more easily and deeply than creosote alone. The sleepers are first steamed for $\frac{1}{2}$ an hour under a 21 lbs. pressure ($1\frac{1}{2}$ atmospheres), and the air evacuated before the emulsion is run in and a pressure of 100 lbs. per square inch applied (7 atmospheres). By this method less creosote is absorbed, yet it penetrates deeper into the wood.—Another recent Continental process (*Buchner's*) consists in first boiling the wood under pressure to get rid of the resin and soluble constituents, and then treating it with a solution of chromic oxide salts, which hardens and tans the fibres, and renders them immune from fungus attacks.

Naphthalining.—Immersion in an open tank containing

heated *naphthaline*, a solid coal-tar product, a process originally introduced in 1882, has recently come into extensive use for estate purposes (fence-posts and stobs) under an improved method, which makes wood like Birch, Beech, Scots Pine, Spruce, &c., more durable than untreated Oak or Larch, and thus giving fencing material that is both cheaper and lasts longer (up to 15 to 20 years).

In *naphthalining*, the crude naphthaline is brought in bags and put into an iron tank heated by steam from a boiler about 20 yards off, the stove for heating the boiler being carefully isolated owing to the inflammability of the naphthaline. The wood to be treated must be thoroughly seasoned; and the drier it is, the better the impregnation. The tank being packed with fence-posts and stobs and then nearly filled with crude naphthaline (which melts at 176° , and boils at 422° Fahr.), steam is applied to raise the heat to over the boiling-point of water (212°). After being kept at this for from two to twelve hours, it is allowed to cool down sufficiently for the wood to be taken out; then other wood and more naphthaline are put in, and the process repeated till all the material has been treated. A tank 21 ft. long and 5 ft. diameter costs about £120, and contains a charge of about 2 tons of naphthaline along with the wood; and when the crude naphthaline costs 35s. a ton at a railway station not far off, the impregnation of tank-loads of mixed hardwoods and softwoods averages about 3d. per cubic foot. The power of absorbing naphthaline is greatest in Scots Pine, Beech, Birch, Alder, and Douglas Fir; much less in Ash, Silver Fir, and Oak; and least of all in Spruce, Larch, and Elm. But creosoting is the preferable method, as naphthalining gives the workmen headaches, is apt to make them feel giddy, and is altogether a more dangerous process.

Powell's saccharisation process is a recent British method for impregnating the woody tissue with molasses, glucose, or sugar. It darkens the colour of wood, and is said to increase

its hardness and density without diminishing its tensile strength, flexibility, and toughness, whilst also slightly decreasing its inflammability. The timber is placed on trolleys and let down into a large tank ($20 \times 9\frac{1}{2} \times 5$ ft.) filled with a solution of syrup or sugar, which is rapidly raised to boiling-point (212° F.) by means of steam circulating through pipes, and then allowed to cool down to 70° by passing water through the pipes; and as the timber cools, the solution is absorbed. The timber is then stored in drying chambers at a temperature of 250° to 300° , and gradually allowed to cool. Conifers and Oak absorb 3 to 4, Willow, Ash, Birch, Elm, and Sycamore 5 to 6, Beech $7\frac{1}{2}$, and Poplar $9\frac{1}{2}$ lbs. per cubic foot; and Larch and Spruce, so difficult to creosote, are as easily saccharised as Scots Pine. Thus treated, Spruce should be well suited for telegraph and telephone posts, &c. It is also claimed for this process that by the addition of certain chemicals (of which alum is probably one) the timber is rendered non-inflammable and fire-resisting.

Dry-rot in timber, due to the saprophytic fungus, *Merulius lacrymans*, appears to be gradually increasing, owing to the use of immature and imperfectly seasoned wood. Infection taking place when felled timber remains stored in the forest is first indicated by red stripes in the sawn wood; and if such wood be thoroughly seasoned, the mycelium is killed, but if seasoning be imperfect, the latent mycelium resumes active growth when the wood is used in building and exposed to dampness—*e.g.*, as when the ends of joists are built into a wall. But the fungus is also often found in woodyards, and from such sources spores or portions of the spreading mycelium are brought into buildings. Thorough ventilation is of importance; and the best *preventive* is painting with antinonnin, or with a solution of corrosive sublimate in methylated spirit (6 oz. to 1 gallon). In timber infected, the spread of the mycelium can be checked by applying carbolic acid.

Fireproofing of wood is also carried out by means of impregnation with borates, silicates, and ammoniacal and other volatile salts; but, though it can be made non-inflammable, no process has yet been discovered for rendering wood incombust-

ible. For superficial coating, oil-paint can be made non-inflammable by adding phosphate of ammonia and borax in the form of impalpable powders; while asbestos paint and mortar made of plaster and asbestos are also used, and give partial security against fire. Of several methods of fireproofing wood by impregnation under strong pressure (though unfortunately always only to a limited depth), *Payne's process* is one of the best, the wood being first impregnated in a vacuum with a strong sulphate of iron solution, then under pressure injected with a solution of sulphate of lime or some alkaline carbonate to make the iron insoluble.

Electricity is also used in France, both to "senilise" wood rapidly in order to make it more durable, and to fireproof it. *Senilising* takes place by impregnating green wood with a 20-per-cent solution of magnesium sulphate warmed to about 90° F., passed in for seven to fourteen hours by an electric current varying from 4 to 6 amperes, and then drying it in the open air; while for *fireproofing*, ammoniacal salts are used in place of magnesium sulphate. And in another French process of senilising, a solution of 10 per cent borax and 5 per cent resin-soap is used in place of the 20-per-cent solution of magnesium sulphate. But as yet it is too early to judge of the success of these methods.

CHAPTER V.

WOODLAND INDUSTRIES : ESTATE SAWMILLS, PREPARATION OF
WOOD - PULP AND CELLULOSE, CHARCOAL - MAKING, RESIN-
TAPPING, ETC.

As a rule, the forester is only called upon to work small sawmills in order to convert timber grown on the estate into posts, stobs, rails, gates, &c., required for fences, and boards, beams, rafters, &c., needed for buildings. Such sawmills are driven either (1) by **water-power**, with vertical mill-wheels, usually overshot, or (2) by **portable steam-engines**, used also for other estate work, or (3) by **fixed steam- or oil-engines** when conversion is large and continuous. But it often happens that the use of a portable engine, working portable saw-benches and circular saws for cross-cutting logs and sawing them up, will enable a great saving to be made in disposing of wood in places distant from a good and ready market ; because by converting on the spot there is a considerable saving on transport in getting rid of the bark and the small sapwood-slabs, for which there may be no sale ; and when such wood is needed for estate purposes close by, the inclusion of a creosoting-plant is also economical. When large sales of timber are made, the wood-merchant usually stipulates for the right to erect portable sawing-machinery either in or near the woods. But on most large estates it is usual to have the sawmill, whether driven by water-power or by steam, stationary at some convenient

centre, from which the needs of the landowner and of his tenants can be easily supplied. If the sawmill can conveniently be put up near the home-farm, it may get the use of an oil-engine, or of a steam-engine which can also be used for the extraction and delivering of timber; but if the woods are small a traction-engine and a portable saw-bench are generally most economical, while in larger woods a stationary sawing-plant will usually be most suitable.

Estate sawmills of small size are worked cheaper by water-power than by steam, although the latter works quicker and can turn out a much larger supply of converted timber (Figs. 85-87); but it is only when steam is used that slabs, tops, and butts, &c., can be converted into railway-keys, small staves, and box-boards, or sold as firewood, or used for preparing oxalate of lime (for oxalic acid) and acetate of lime (for acetic acid), or for making wood-wool, or using the sawdust for litter and manure, &c.

Where the timber has only to be conveyed for 2 to 3 miles a stationary sawmill is the more economical, but for long haulage, the use of a traction-engine and a portable saw-bench usually pays best.

Sometimes the machinery of stationary sawmills is driven by **turbines** or horizontal water-wheels, which utilise a small water-supply very well, but require a high fall of water. The simplest and oldest form of **water-wheel** was the over-shot vertical wheel, worked by the force of a good volume of water having a low fall. The impetus thus given was conveyed to an inner wheel, at the end of the axle of which was a revolving crank with a movable lever attached (*pitman*), fastened at its upper end to the bottom of a framework (*gate*) to which a single vertical saw was attached, running in grooves between two stout posts. At each turn of the water-wheel the crank revolved and alternately raised and lowered the frame-work containing the saw, each downward stroke cutting into the log, and the teeth of the saw being set slightly downwards

Fig. 85.—Saw Bench for Staves and Pit-wood.

Fig. 86.—Long-saw Benches for long Logs.

Fig. 87.—View of small temporary Sawmill.

in order to make the stroke more effective. The log that was being sawn rested on a bench, which was moved forward by an automatic arrangement of levers, toothed wheel, and ratchet, so as to bring the log up to the saw at the rate required. Where there is good water-power circular saws can also be driven by water-wheels, though their rate and strength of cutting is not so effective as steam-driven circular saws.

The first improvement was to arrange a gang of two or more saws in the frame, these multiple-saws having shorter and thinner blades which work more quickly, but with a shorter stroke, and cause less waste in sawdust. But in any case the stroke of vertical saws is twice the length of the crank, and must be a little over twice the thickness of the thickest part of the log that is to be sawn.

A further improvement was the *muley saw*, with its upper end hung in side-slides attached to an overhead beam and the lower ends of the saws attached to a bar directly joined to a pitman, thus doing away with the heavy gate and side-posts of the older saw-frame, and allowing the saws to be slightly inclined forwards so as to give a more effective cutting-stroke in each downward movement.

Circular saws vary from 2 to 4 ft. in diameter for water-power and small steam-power estate-mills, and up to 6 ft. diameter in large timber-mills. They vary considerably in thickness and in quality, but must be strong to cut through knots, the ordinary thickness being from 12 to 16 gauge (12 being thicker than 16). In large sawmills vertical multiple-saws seldom exceed 14 gauge, and are sometimes only 18 gauge, wasting only $\frac{1}{8}$ in. in sawdust. In large mills there may be up to 30 vertical saws in the frame, but single horizontal frame-saws and endless band-saws (horizontal or vertical) are used with a fine gauge (Figs. 88-90).

Cross-cutting circular saws, for sawing across the grain of wood, are reciprocating and with almost upright teeth, while **slitting or ripping saws** have their teeth set more at a forward

angle (Fig. 89); frame-saws have J-shaped teeth with cutting points facing downwards (Fig. 90). *The thickness or gauge*, 12 to 16, varies according to kind of wood to be sawn, the smaller gauge or thicker saws being needed for hardwoods and resinous Conifers, and the thinner saws of higher gauge being used for softwoods and non-resinous Conifers; but the circular saws have, for stability, to be thicker than the vertical frame-saws, and therefore cause more waste in sawdust. For portable estate-

Fig. 88.

Teeth of Band-Saw.

Fig. 90.

Teeth of Frame-Saw.

Fig. 89.

1

2

3

Teeth of Circular Saws.

1. Wide-pitched, strong-hooked teeth of Ripping-saw for soft-woods.
2. Triangular arrow-shaped teeth of a Cross-cut saw.
3. Slightly-hooked and less wide-pitched teeth of Ripping-saw for hardwoods.

mills a 10- to 12-horse-power engine with high-pressure boiler and furnace suited for burning waste wood is the most convenient. It costs about £300-£350, whereas a traction-engine of similar power would cost £500-£550.

A 12-H.P. engine can drive 4 circular saws (one cross-cutting and 3 ripping-saws), or in all 4 ripping-saws when cross-cutting is finished.

The speed of circular saws depends of course on the driving-power, and varies greatly in water- and in steam-power mills.

In vertical frame-saws the number of strokes in old mills varied from about 70 to 120 per minute, while in new mills it may average about 180 to 200 strokes per minute. Circular saws of medium size can be made to travel with a comparatively low motive-power at from 50 to 70 ft. per second for hardwoods and from 50 to 100 ft. per second for softwoods, according to the driving-power. Band-saws require less driving-power, and waste less in sawdust. With circular saws, the greater the speed the more is the waste in sawdust. The number of revolutions per minute can be easily calculated from the speed of the saw at its circumference, and usually is 400 to 500 for a 48 in. saw. Saws of a smaller diameter and proportionately thinner require less driving-power than larger and thicker saws; and the greater the diameter, the less should be the driving-speed. A good cross-cut saw should be $3\frac{1}{2}$ ft. in diameter and number 12 gauge, while the ripping-saws can be 36 in. diameter and 14 to 16 gauge. Saws should be of the very best cast-steel, and varying in thickness according to the work to be done; but the thicker the saw, the greater the waste in sawdust, which may amount to about 25 to 35 per cent of the total volume of wood (and which was intended to be covered by the square-of-quarter-girth measurement of logs).

There are no absolute standard sizes for converted timber, for the dimensions most in demand vary locally.

Logs may be *rough-hewn* with axes, or *sawn* on all four sides to form *squares* or *balks*. The strongest beam obtainable from a log is when the sides are cut in the proportion of $1 : \sqrt{2}$, or 5 : 7, as this ratio gives the maximum product of *breadth* $\times$ *height*. A log or balk halved lengthways forms two *half-balks*, and if divided lengthways into four equal pieces is *quartered*, and forms four *quarter-balks*; and when sawn to smaller dimensions, but in the full length of the log or log-section, timber is known by the trade terms of *scantlings*, *planks*, *deals*, and *battens*, which are always obtainable of more

or less standard sizes from timber-yards **Scantlings** are over 4 in. wide, and at least 4 in. thick ; **planks** are at least 10 in. wide, and from 2 to 4 in. thick ; **deals** are 9 in. wide, and from 2 to 4 in. thick ; **battens** are 7 in. wide, and from 2 to 4 in. thick. On the Clyde the customary sizes are : **scantlings** and **battens**, 10 ft. and upwards $\times$ 4 in. to 6 in. $\times$ $1\frac{1}{2}$ in. to 3 in. ; **deals** and **planks** 12 ft. to 15 ft. and upwards (but averaging 18 ft. to 20 ft.) $\times$ 10 in. and upwards $\times$ 3 in. and upwards. These are further reduced to **boards** of 6 to 12 in. wide and $\frac{1}{2}$ to 1 in. thick, and **laths** from 1 to 4 in. broad and $\frac{1}{2}$ to 2 in. thick.

By trade custom 120 **deals** = 100 ; 1 **square of flooring** = 100 superficial ft. ; 1 **load of timber** = 40 cubic ft. *in the rough* and 50 cubic ft. *squared or converted* ; 1 **load of planks** = 600 square ft. of 1 in., 400 of $1\frac{1}{2}$ in., 300 of 2 in., 240 of $2\frac{1}{2}$ in., 200 of 3 in., 170 of $3\frac{1}{2}$ in., and 150 of 4 in. ; a **ton** is sometimes 40 cubic ft. (*hardwoods*), sometimes 50 cubic ft. (*softwoods*), for railway carriage, and sometimes deadweight avoirdupois (as timber is usually sold in Ireland) ; and a **cord of wood** or **stack of fuel** is $2\frac{1}{2}$ tons (125 cubic ft.), or a cubic fathom (216 cubic ft.), or other size by local custom.

When logs of 8 ft. or more in girth are being converted into boards, they are often first quarter-barked and then sawn as

Fig. 91.

Conversion on the quarter.

much as possible **on the quarter**—*i.e.*, in the direction of the medullary rays—so as to display the best flowering and grain. There are several methods of converting on the quarter, but two of the simplest are shown in Fig. 91, where the various alternate and successive saw-cuts can be easily

seen, as well as the final remnants that can be used as fence-posts, &c. **Cleft timber** is the best for oars, cask-staves, wheel-spokes, paling-wood, gate-rails, ladder-rungs, trenails or wooden pins, &c.

For **Sleepers** the standard size is 9 ft. $\times$ 10 in. $\times$ 5 in. ($= 3\frac{1}{8}$ cubic ft.) For 1 sleeper the small end of the section of log must be over 10 in. in top-diameter; over 14 in. diameter gives 2; over 18 in., 3 full-sized sleepers (and can also give other 2 of small size); and a log of $22\frac{1}{3}$ in. top-diameter will give 6 good sleepers (4 from the centre beam and one from each of two big side-slabs). The output of sleepers varies from 64 to 77 per cent of the total cubic contents of a log, while from 23 to 36 per cent goes into slabs and sawdust. Log-sections of $22\frac{1}{3}$ in. top-diameter give the largest out-turn (77 per cent in sleepers).

Pitwood, whether sleepers or props, is of various local dimensions, as different pits use different sizes. Sleepers vary from $2\frac{1}{2}$ ft. $\times$ 5 in. $\times$ $2\frac{1}{2}$ in., up to 3 ft. to 5 ft. $\times$ 4 in. to 6 in. $\times$ 2 in. to 4 in.; props vary from $2\frac{1}{2}$ ft. to 6 ft. long by a minimum diameter of $2\frac{1}{2}$ in. (3 in. over bark) at top-end; and bars vary from 6 ft. to 9 ft. with a top-diameter of 4 in. to 6 in. But, unless collieries are near at hand, pitwood is usually sold in complete pole-lengths down to 3 in. top-diameter over bark.

The cost of conversion varies greatly according to the dimensions into which the wood is cut. Sleepers of standard size (9 ft. $\times$ 10 in. $\times$ 5 in.) can be turned out of large mills at a cost of about $1\frac{1}{4}$ d. each. And whereas hand-sawing costs for softwoods 2s. 6d. to 3s., and for hardwoods 3s. 6d. to 4s. 6d. per 100 superficial feet of boards, and 3s. 6d. to 5s. for softwoods, and 5s. to 7s. for hardwoods per hundred superficial feet of planks, the mill-sawing and stacking can be done for about 4s. per 1000 superficial feet of $\frac{3}{8}$ in. boards, and up to 7s. 6d. per 1000 superficial feet of 1 in. boards. The sawing of Scots Pine boarding costs per 1000 superficial feet about 4s. 6d. for $\frac{1}{2}$ in., 5s. 6d. for $\frac{5}{8}$ in., 6s. 6d. for $\frac{3}{4}$ in., and 7s. 6d. for 1 in. boards. Sawing Larch stobs, 6 ft. $\times$ 6 in. $\times$ 3 in. costs about 4s. 8d. per 100, and rails 3 in. $\times$ 1 in. to $1\frac{1}{4}$ in.

about 7s. 6d. per 1000 running ft. For working up small material the payment to be made to saw-mill hands is best arranged by piece-work according to the amount of handling and the time required in conversion into mill-rollers, shuttle-blocks, small boarding, railway-keys, &c. For felling and cross-cutting into lengths of 6 ft. and upwards prices vary, for Scots Fir and Larch $\frac{1}{2}$ d., Spruce $\frac{3}{4}$ d. to 1d., and hardwoods 1d. to 2d. per cubic ft., while the sawing and stacking comes roughly to $1\frac{1}{4}$ d. to $1\frac{1}{2}$ d. per cubic ft.

Wherever possible, small waste-wood, slabs, and sawdust should be utilised. If not saleable as fuel, small wood can be worked up into wood-wool ("manilla shavings") for packing, while the sawdust can be used as litter or for cleansing floors, stuffing pin-cushions, &c. Where large quantities of sawdust have to be disposed of, it may even pay to make briquettes; while the slabs and waste wood may be used for preparing pyroligneous acid or wood vinegar, from which wood-naphthia or wood-spirit is derived for methylated spirits, and also oxalate of lime and grey acetate of lime for further chemical processes. But these bye-products can only be profitably worked on a large scale, and under specially trained operators.

The greatest loss in sawdust takes place in wood with tough fibres, which are hardest to saw (*e.g.*, Poplar, Willow, Lime, and Birch). But in estate sawmills unnecessary loss is often caused by using thick saws, even when of small diameter. For example, to cut 4000 superficial ft. of 1 in. Larch boarding with a No. 16 B.W.G. circular saw needs 366 ft. of rough timber, while 386 $\frac{1}{2}$ ft. will be needed if a No. 12 saw be used; and counting transport, wages, and milling time, the extra cost will in the latter case be about 27s. 6d., while over 20 ft. will have been unnecessarily lost in the form of sawdust. And when conversion is being carried out on an extensive scale, the loss may become very considerable.—Sawdust is used extensively for stuffing pin-cushions and dolls, cleaning dirty floors, making oxalic acid, pressing and moulding into briquettes (along with more inflammable substances), and in the carbonating stage of preparing soda-ash. It is also used as a litter for farm stock. The sawdust briquettes made in Sweden by Heidenstam's process are said to have nearly double the average heating power of air-dried wood, and to equal

that of good coal. Additional uses for sawdust are constantly being found. Flour made from it can be used as a component material in manufacturing dynamite, linoleum, xyolite, &c. The wood-flour can be ground in a cheap mill, similar to those for grinding corn and rye; and pine and spruce sawdust passed through the stones and packed ready for shipment is worth about 50s. a ton. One important use for wood-flour is in making dynamite, as it absorbs nitro-glycerine, the explosive ingredient. But wood-flour dynamite is inferior to that made with infusorial earth, though there are many purposes for which it serves and is cheaper. It is also used for linoleum, mixed with linseed oil, to give body to floor coverings. It is not equal to ground cork for this purpose, as it is less elastic; but it is cheaper, and suitable for medium grades. Wood-flour is also used for xyolite, an artificial flooring resembling wood in weight and stone in other respects, for kitchen floors, halls, corridors, &c. It is impervious to water, and practically fireproof. It is even used for floor material in German war-vessels, as it is not liable to take fire or splinter if struck by shells.

The Preparation of Wood-pulp and Cellulose is, next to saw-mills, now by far the largest and most important woodland industry, which has assumed enormous dimensions during recent years. The woods most suitable for pulping are those that are soft—Lime, Aspen, Poplar, Willow, and among Conifers Spruce especially, then Silver Fir. Scots Pine and other very resinous Conifers are difficult to pulp owing to their resin.

When the woody substance is prepared by mechanical means only it is called **Wood-pulp**, and when it is obtained chemically it is called **Cellulose**, which is always worth over one-half more than wood-pulp.

Lime, Aspen, and Poplar give the finest and whitest pulp; but Spruce, which gives a pale yellow pulp, becoming darker and duller, is now chiefly used both for wood-pulp and for cellulose, owing to its being the only wood obtainable in the enormous quantities that are now needed throughout the world for paper-making.

Wood-pulp is the disintegrated woody fibres separated mechanically by grinding. It retains its original colour, and is

not bleached (hence the superiority of the white woods above noted). The best size of wood for pulping or for cellulose consists of poles of from 4 in. to 6 in. top-diameter and 6 in. to 8 in. bottom diameter, cut into lengths of about $6\frac{1}{2}$ ft. These sections have to be first cleaned and barked, then freed from knots and unsound parts, and cut into convenient lengths before being ground into pulp or chipped for cellulose-making.

In grinding the wood mechanically for pulp, the billets are pressed lengthways against a hard fine-grained sandstone grinding-stone, rotating quickly with a continuous stream of water dropping between the wood and the stone, to make the woody fibres separate more easily; and the fibres are then strained, dried, and pressed. The grinding-stones are from $3\frac{1}{2}$ ft. to 5 ft. in diameter and about 18 in. to 20 in. thick. The pulp-wood is put, 5 or 6 billets at a time, into a box and pressed steadily against the grindstone, and the pulped fibres are carried off on to sieves for straining, these sieves being set at a slight angle and shaken from side to side by means of a crank, there being usually two or three sets of such strainers set one above the other with different-sized meshes. The fine fibres are then pumped up into a churn, reduced there still further by friction, then again passed through strainers, and led off to rollers or to a pressing-machine to get rid of the water and to dry the pulp. Wood-pulp made thus is dull in colour, unbleachable, and the short thick fibres can only be used for coarse paper, pasteboard, or cardboard. It is known as *white pulp*, but if the wood be steamed under pressure of about 60 lbs. per square in. before being ground, the pulping is easier and the pulp-fibres longer, softer, and more flexible and felty, but darker in colour (*brown pulp*). The making of wood-pulp is now confined to places having good water-power, but far distant from a cellulose-mill, or where there is not a sufficiently large and constant supply of wood to keep a cellulose-mill always at work.

Cellulose is the commercial product obtained from wood first cut into thin slices and small chips by machinery, then ground down between grooved rollers, and boiled under high pressure in a solution either of soda (*alkali process*) or of calcium sulphite (*acid process*, and usual method). The **Alkali process** is the older, but the more expensive, and though it yields a finer quality of cellulose, there is more loss of cellulose through the wasteful action of the caustic soda (NaHO) in dissolving the lignin; and it has the further disadvantage of creating an abominable stench. The **Acid Process** is therefore now generally used, in which the macerating agent is *bisulphite of lime*, $\text{Ca}(\text{HSO}_3)_2$, obtained by dissolving sulphate of lime, CaSO_3 , in hydrated sulphurous acid, H_2SO_3 , the sulphurous acid, SO_2 , being the active agent in dissolving the ligneous matter encrusting the cellular tissue of the woody substance, without wasting the cellulose itself so much as in the alkali process; while the cellulose got thus is also easier to bleach than alkali-processed cellulose, though it is less soft and pliable. All the wood used has to be carefully cleaned, barked, and freed from branch-knots and unsound parts, then chipped diagonally into small pieces and ground up before being packed and boiled with bisulphite of lime lye in large glazed barrel-shaped masonry vats. The bisulphite of lime lye is obtained by burning sulphur or iron-pyrites in furnaces and leading off the sulphurous acid evolved into a lofty tower built up of wood and iron, and packed with limestone down which water continually trickles from a perforated tank at the top, a weak solution of hydrated sulphurous acid, H_2SO_3 , being thus obtained, and acting upon the carbonate of lime in the limestone, CaCO_3 , and forming bisulphite of lime, $\text{Ca}(\text{HSO}_3)_2$. The lye is led off into the large glazed masonry vats packed with ground chips, which are then boiled under a pressure of about 80 lbs. per sq. in., the heating taking place by hot steam at 260° or more for about 40-60 hours, when the sulphurous acid is carried off again to the limestone-tower, and

the cellulose vat is then washed out by running water through it before men can go down to shovel out the pulp. The raw cellulose is next placed in water-troughs slightly inclined and kept constantly shaken slightly from side to side, then led off with flowing water over a long succession of troughs to free the pulp from impurities ; but before being thus strained it is, whenever necessary, *bleached with chlorine* to the extent required, any unnecessary bleaching being avoided, as it lessens the strength and elasticity of the felty fibre. In its passage down the water-troughs, the fibres become finer and more equally distributed in the water, until at last they are fairly equally deposited in one broad sheet upon a roller of felt which leads them off to revolving drums, where they are pressed to free them from water, then carried between heated rollers which further dry and compress the pulp now formed into paper, and wind it into rolls. There is but little loss in weight by this process ; but softwoods like Willow and Poplar and Conifers like Spruce and Silver Fir are easiest and cheapest to treat, and are therefore preferred. One ton of dry wood gives about 6 cwt. of cellulose (30 per cent) by the alkali process, and 10 cwt. (50 per cent) by the acid process, and the value of the cellulose is about £7, 10s. per ton.

To enable a small cellulose-mill to be worked profitably, at least 80 cubic fathoms or about 12,000 cubic ft. of wood are needed weekly, equal to 4000 fathoms or 600,000 cubic ft. per annum. This equals the yield from about 120 to 150 acres of 40- to 50-year-old Spruce, yielding from 4000 to 5000 cubic ft. per acre according to the quality of the soil and of the crop, so that probably about 6000 acres of well-managed Spruce-woods would be needed to supply even a small cellulose-factory. But thinnings of 4 in. to 6 in. top diameter and 6 in. to 8 in. bottom diameter are very suitable for pulping ; and wherever there are very much larger woodlands, thinnings from them could well be thus utilised.

Spoke-shaving by hand of poles to free them from bark causes a loss of about 7-8 per cent, while bark-paring by machinery wastes about 15-16 per cent.

Cellulose forms a raw material for several industries. Treated with sulphuric acid it makes vegetable parchment, and with nitric acid gun-cotton, which is again used in producing the hard celluloid forming imitation ivory for combs, billiard-balls, &c., when mixed with an equal weight of camphor.

Charcoal-burning, formerly an important rural industry in Britain before coal was used for iron-smelting, is now only practised extensively in the forest of Dean and in some parts of the Midlands, though elsewhere lop, top, and waste wood not needed for fuel is made into charcoal for estate and smithy purposes. Charcoal can be made from any kind of wood, but the best quality for making gunpowder is yielded by the alder-buckthorn and dogwood shrubs, and by Alder, though Birch and Oak were also largely used for this purpose. Charcoal-burning is the dry distillation of wood by carbonising it under partial exclusion of air in pits, kilns, or stacks. This causes a certain loss of carbon through partial combustion, owing to oxygen being only partially excluded,—because, after the watery sap is evaporated at 212° Fahr., the decomposition of the woody substance begins at about 300°.

The oldest British method of charcoal-burning was to dig pits about 4 ft. deep in the ground, with sloping walls, then throw in brushwood, set fire to it, and throw in wood till the pit was full, then cover with turf and earth and allow it to carbonise and cool down for a day or two before reopening and taking out the charcoal. This wasteful process only gives about 30 bushels of charcoal per cord or stack of 120 cubic ft.

The improved British method consists in burning in dome-shaped kilns built up with billets of wood from 15 in. to 24 in. long, so as to form stacks of 12-15 ft. in diameter on level hearths. A large pointed billet split crossways at the top end

is fixed in the centre, and two bits of wood set at right angles through the clefts ; and in each of the right angles thus formed a billet of wood is laid thick end down against the centre post, while large straight billets are laid radially on the ground like the spokes of a wheel to form a floor, the spaces between being filled with small branches or brushwood. These flooring billets are held in position by pegs driven into the ground round the circumference of the stack, and about a foot apart. On this ground-floor, the first stage of the kiln is built up with the largest billets set thin end up and inclining slightly inwards towards the central stake ; then another storey of shorter billets is laid similarly above this ; then an upper layer of smaller stuff ; and the top is rounded off with small wood to form a paraboloid cone. The stack is then covered with turf and surfaced with mixed earth and sand, and the kiln is lighted by drawing out the central billet in the upper layer, and filling and lighting pieces of dry wood. The burning usually takes 4 or 5 days, according to the size of the kiln and the state of the weather ; and great attention has to be paid, both day and night, to regulate the course of the firing, by closing openings where flames appear, showing unnecessary combustion ; but vents are opened with a sharp stick to equalise the rate of carbonisation all round the stack, being closed, when no longer required, with earth and sand (as shown by colour of smoke). When the firing is complete right down to the circumference, all vents are stopped, more earth is thrown on, and the kiln is allowed to cool before being opened to remove the charcoal.

The contents of such a stack are known from the amount of cordwood used, but can also be reckoned by multiplying the square of the circumference into the height and dividing by 9π (28·25) ; because, the contents of a true cone being $\frac{1}{3}$ (basal area $\times$ height), and of a paraboloid cone being $\frac{1}{2}$ (basal area $\times$ height), the actual contents of such a stack will be about $\frac{4}{5}$ (basal area $\times$ height).

The usual Continental method is very similar (Fig. 92); but the kiln is built up with billets about 3 ft. long, and those over 6 in. diameter are split; and in building up the kiln the largest pieces are put halfway between the centre and the circumference, where the heat is strongest, while the lighting usually takes place from below by withdrawing a pole originally laid on the ground when the kiln is being built up. The lowest layer of billets rests directly upon the ground, and not on a staging, and split billets are set face inward. The kiln is first covered with turf, moss, bracken, conifer sprays, &c., and then top-covered with earth and charcoal

Fig. 92.

Dome-shaped (Paraboloid) Charcoal-Kiln.

- a.* Central section; showing arrangement of wood in kiln (with largest billets about half-way between centre and circumference).
b. Outer view; showing smoke-vents, and lower and upper supports.

dross, this surface-coating varying from about 3 in. to 10 in. in thickness, according to circumstances, and being supported by wooden rests. The kilns are large, up to 2000-3000 cubic ft. on permanent hearths, but about 1000 cubic ft. on temporary hearths; and the hearth is made to slope slightly from centre to circumference, sheltered places being of course chosen, and, if necessary, protecting screens erected against winds. Old hearths are best, and the kilns are built up, so far as possible, of only one kind of wood, to equalise the rate of carbonisation. For the first hour or two the kiln "sweats", and gives out pungent, acrid smoke, and there is always a chance of an explosion through rapid conversion of the moisture into steam. Carbonisation begins about an hour or two after

lighting, but sweating continues for most of the first day. At about 12 to 16 hours shrunken hollows are opened and quickly filled with wood; and when the sweating-stage is ended smoke-holes are opened with a pointed stick to regulate combustion, as shown by the colour of the smoke issuing, and the success of the charcoal-burning depends greatly on the manipulation of these smoke-holes. When carbonisation is completed down to the circumference of the kiln all the vents are closed, moist earth is thrown over the kiln, and it is allowed to cool down for twenty-four hours before being opened. Large kilns on permanent hearths take about 10 or 12 days to burn, while kilns of about 1000 cubic ft. take 5 or 6 days. The charcoal is drawn at night while still hot, and is sprinkled with water to prevent its glowing again. Then it is assorted into foundry and smithy charcoal, and smaller pieces are passed through wire-screens and also assorted. But everywhere on the Continent charcoal-burning is now a decadent industry owing to the new wood-pulp and cellulose factories.

Good charcoal should be deep black in colour, with a steel-blue metallic sheen, and lustrous across a transverse section, and when two pieces are clinked together they should give a metallic sound. Charcoal that is reddish-brown is incompletely carbonised, while softness and dull colour indicate over-burning or unsound wood. Its specific gravity averages about 0.20; but hardwoods produce heavier and better charcoal than softwoods, well-seasoned wood more than greenwood, and large billets more than small billets; and the slower the process of carbonisation, the heavier is the charcoal. Good kiln-burned charcoal should give in volume from 50 to 60 per cent of the wood used, and in weight about $\frac{1}{4}$ of its original weight; and it usually weighs about one stone per bushel. A ton-weight of wood produces about 40 bushels of charcoal on the average, but only about 36 if all hardwood, and about 43 if all softwood—though these average figures may vary greatly according to circumstances.

Charcoal-making costs about 1d. per bushel, or 13s. 4d. per ton, and it sells at about 60s. per ton; and as 4 tons of cordwood give about 1 ton of charcoal, this shows 46s. 8d. in all, or 11s. 8d.

per cord of 1 ton, as including the price of the wood and the profit earned. But in practice the cordwood is sold to the charcoal-burners at a price which often enables them, when working in pairs, to earn about 35s. to 40s. per week each.

Charcoal is now also largely obtained as a bye-product in the fractional distillation of the substances contained in wood by treatment in masonry furnaces or iron retorts at a high temperature. At 300° to 550° Fahr. *crude pyroligneous acid* or *wood vinegar* is given off, and *wood-tar* ("Archangel tar") at 625° to 800° Fahr., while the charcoal remains as the residuum.

Resin-tapping for *Turpentine* and *Rosin* is not likely again to be of importance in British forestry.

(1) *In France*, resin-tapping of the Maritime Pine takes place around Bordeaux on trees over 3½ ft. in girth, when small incisions are made in the bark and gradually heightened during the following five years, when they are about 12 ft. high and 4 in. broad.

(2) *In Austria* the Austrian Pine is tapped by making a broad incision near the foot of the stem, and hollowing it out into a deep cup-shape at the bottom, in which the resin collects. Tapping is continued for about ten years, the wound being gradually increased in height by about 15 in. a-year, and the tapping-season continuing from April to middle of October, *i.e.*, during all the season of active growth. The trees are only tapped in one place.

(3) *The German method* of tapping Spruce is by making two incisions into the sapwood in May or June on opposite sides of the stem, for about 4 ft. high by 2 in. broad, and ending in a point at the lower end, and the resin of the first year is scraped off in the following July; then the edges of the incision are freshened, and so on for about 10 to 12 years.

(4) *The Alpine method* of tapping Larch, the resin of which is mainly obtained from the heartwood, consists in boring a hole with an augur about 1¼ in. in diameter, and giving

the boring a slightly upward slant right into the centre of the heartwood about a foot above the ground, and then plugging up the hole with wood. In Autumn the resin which collects there is scooped out, the hole is again plugged up, and the fresh resin is collected annually for twenty years or more.

Crude resin is used for distilling *oil of turpentine*, and the residuum left is *rosin* or *colophony*. Distillation takes place by boiling the crude resin in a closed vessel over an open fire, and adding water as the resin melts. As the oil of turpentine evaporates it is carried off along with the steam through a glass cooling-worm into a flask-shaped receiver, the condensed vapour forming water and the oil floating on the top of it. When all the oil has been evaporated the lid of the boiler is removed, and what remains is further boiled until it becomes transparent, when it is poured through wire-strainers to remove impurities, and then run into boxes or casks for transport, where it on cooling solidifies into the ordinary dark-brown rosin.

On the average, crude resin gives about 15 to 30 per cent of oil of turpentine and 65 to 75 per cent of rosin, with 5 to 10 per cent of impurities and loss in distillation.

Silver Fir and Larch give most turpentine, Maritime and Austrian Pine less, and Spruce least.

Potashes are now only made in places where wood has small value. The process consists in burning wood to reduce it to ashes, and then extracting the potash-lye from the crude ash in five vats ranged one above the other, and filled for about $\frac{2}{3}$ with crude ash and $\frac{1}{3}$ with water. After 3 to 4 hours' soaking the liquor from the top vat is run off into next vat, and so on for the 2nd, 3rd, and 4th vats. The concentrated lye from the 5th vat is then run off into shallow iron pans and evaporated over a furnace until only *raw potash*, a loose, friable, blackish-brown substance, is left. When the contents of vat 1 have been drenched five times the potash is thoroughly extracted; then its contents are thrown out, fresh ashes are put in, and it is made

to take the place of the lowest vat—each vat being meanwhile moved up one step.

The crude potash is calcined in a fire-proof furnace to drive off the moisture thoroughly, when it becomes a white powder ready for packing into barrels. In calcining, from 10 to 20 per cent of the raw potash is lost. Even on the Continent potash-burning in the woods has now almost entirely given place to preparation in chemical works.

Grazing in woodlands may often be profitable when woods are about twenty years of age, and begin to show an undergrowth of grass, as is especially the case in Larch woods; and when a fall is left fallow for two or three years to obviate attacks of the Pine-weevil, the grazing is sometimes well worth having. Woodland grazing is reckoned to have from $\frac{1}{2}$ to $\frac{2}{3}$ the feeding-value of good meadow grass.

The improvement in the grazing value of the land was formerly estimated to be of itself sufficient to make Larch-planting beneficial in the Highlands of Scotland, quite apart from the profit obtainable from timber.

- Abele (see "Poplar").
Abietinæ, 5, 17.
Acacia, False (see "*Robinia*").
Acid process for cellulose, 321.
Acorn-dibbler, 58.
Actuarial methods applied to Forestry, 139.
Æcidium stage of fungi, 237, 245.
Afforestation, Royal Commission on (1909), 24.
Agaricus, fungi of genus, 237, 251.
Age-classes in woods, 106, 128, 134.
Age of trees and timber-crops, estimate of, 98.
Agricultural implements, timber for, 279.
Agrilus viridis, 193, 208.
Agriotes lineatus, 193, 209, 230.
Air-drying of wood, 300.
Alburnum, 269.
Alder, 5, 7, 10, 14, 16.
 ,, -bark, 288.
 ,, weevil, 192, 205.
Alkali process for cellulose, 321.
Anatomical structure of wood, 264.
 ,, ,, identification from, 266.
Annual fall, different methods of fixing the, 123-129.
 ,, falls, allocation of, 120.
 ,, ,, normal distribution of, 106.
 ,, income, capitalised value of, 140.
 ,, increment, 98.
 ,, rings in trees, 29, 265.
- Antiseptic preservation of timber, 299, 303-309.
Aphideæ, 195, 225-227, 232.
Aphis of Spruce and Larch, 195, 226.
Appendices to Part II., *Management and Valuation*, 147-156.
Apterococcus fraxini, 195, 227.
Arboriculture, British, 21, 22, 77.
Arborvitæ (see "Red Cedar").
Argyresthia lævigatella, 194, 219, 231.
Aridity, damage by, 253.
Aromia moschata, 193, 208, 230.
Artificial drying of wood, 301.
Ash of wood, 268.
Ash, the Common, 4, 6, 8, 12, 16.
 ,, the Mountain (see "Rowan").
 ,, natural regeneration of, 85.
 ,, -bark beetles, 192, 198, 199, 228.
 ,, -scale, 195, 227.
Aspen (see "Poplar").
 ,, -leaf beetle, 193, 209.
Assize of Woodstock (1184), 20.
Atmospheric humidity in woodlands, 26.
 ,, impurities, damage by, 254, 259.
 ,, temperature in woodlands, 26.
Auction-sales of timber, 286.
Angur-worm, 194, 219.
Austrian Pine resin-tapping, 327.
Automatic girth-measurement, 95.
Average prices of timber, 279.
 ,, Yield Tables, 97, 101.
Avondale Forestry School, 24.
Axe, felling with, 280, 281.
 ,, and saw, felling with, 280, 282.

- Balks, 315.
 Balls of earth, planting with, 68.
 Band-saws, 313, 314.
 Barb-wire fences, 166-169.
 Bark-allowance, 90.
 " -beetles, 192, 195-201, 228.
 " -binding, 254.
 " for tanning, different kinds of, 288.
 " harvesting and drying of, 288.
 " -mosses, 234.
 " -scorching, 60, 257, 258.
 " -stripping by deer, 171.
 " " of Oak, 288.
 Barrel-making timber, 279.
 Barren sand-dunes, planting of, 74.
 Basket-making, Osier preparation for, 288.
 Battens, 316.
 Bavarian drill-board, 57.
 Beam-tree (see "Whitebeam").
 Beard-mosses, 234.
 Beating up blanks, 74.
 Beech, 5, 6, 9, 14, 15.
 " branch-tuft, 252.
 " leaf-mining weevil, 192, 205, 229.
 " natural regeneration of, 84.
 " -scale, 195, 227.
 " -seedling fungus, 236, 237.
 " -spinner moth, 211, 230.
 " stump-tuft, 237, 251.
 Beetles, 183, 192, 195.
 " destructive, 192, 195-210, 228-230.
 " extermination of, 189.
 " useful, 186.
 Bethell's preservative process, 303, 304.
 Bills or billhooks, felling with, 280.
 Birch, 5, 7, 11, 14, 16.
 " -bark, 289.
 " -rust fungus, 237, 246.
 Birds, useful and destructive, 177-180, 186.
 Black Arches moth, 193, 212.
 Blackcock, damage by, 177, 178.
 Black Pine-cambial beetle, 192, 198.
 Bladder-fungi, 246.
 Blanks, filling of, 74.
 Blight Insects, 195, 225-227, 232.
 Blister-fungus, 246.
 Blueing of conifer timber, 273.
 Bluestone, impregnation with, 303, 304.
 Board measurement, 90.
Bombycidae, 193, 210-213, 230.
 Book-keeping for woodlands, 138.
 Bordeaux mixture, 239.
 Bordered White moth, 194, 215, 231.
Bostrichini, 192, 199.
Bostrichus, insects of genus, 192, 199-201.
Botrytis cinerea, 236, 239.
 Boucherie's preservative process, 303, 304.
 Boundary-marks, 159.
 Bracken, clearance of, 51.
 " -clock, 193, 208, 229.
 Brakes on rafts, 298.
 " on timber-slides, 296.
 Branch-knots, 272.
 " -rot, 273.
 " -tuft fungus, 252.
 Breaking-strain, resistance to, 274.
 British Forestry, national system of, 21, 22, 77.
 " timber, market value of, 279.
 " technical uses of, 277-279.
 Broadcast sowing, 54.
 Broad-leaved trees, 4, 6-17, 266.
 Brown-tail moth, 193, 211.
 Buchner's preservative process, 306.
Buprestidae, 193, 208.
 Burnett's preservative process, 303, 304.
 Butterflies, 183.
 Cabinet-making timber, 279.
Caeoma-stage of fungi, 236, 243.
 Calcining of potashes, 328.
 Calcium-sulphite process for cellulose, 321.
 Calliper for measuring timber, 95.
 Cambium, 29, 269.
 Canker of broad-leaved trees, 236, 242.
 " Larch-, 236, 240.
 " Silver Fir-, 245.
 " Pine-, 248.
 " Spruce-, 243.
 Canopy, normal density of, 106, 107.
 Capercaillie, damage by, 177, 178.
 Capital in wood, normal, 106, 108-112, 141, 142.
 " required in Forestry, 104.
 " value of woodlands, 141, 142.
 Carpentry, timber for, 278.
 Carbonisation of wood, 323-327.
 Carting timber, cost of, 292.
 Carts, timber-, 291.
 Cask-making timber, 279.
 Cattle, damage by, 165.
 Causes of decay in timber, 276, 299.

- Caustic soda process for cellulose, 321.
Cecidomyia, insects of genus, 195, 225, 232.
Cecidomyidae, 195, 225.
 Cedar, Red (see "Red Cedar").
 Celluloid, 323.
 Cellulose, 268, 319, 321.
 " preparation of, 319, 321.
Cerambycidae, 193, 208.
Cerastoma piliferum, 273.
Cercospora acerina, 236, 238.
Cerura vinula, 193, 210, 230.
 Chafers or beetles, 183.
 Chain-lever for timber-felling, 282.
 Characteristics of trees, Sylvicultural, 33-39.
 Charcoal-burning, 323-327.
 Charring of timber, 303.
Cheimatobia brumata, 194, 214, 231.
 Chemical composition of wood, 268.
Chermes, insects of genus, 195, 225-227, 232.
 Cherry, 8, 10, 11, 13, 17.
 Chestnut, Horse-, 5, 6, 7, 12, 16.
 " Sweet or Spanish, 5, 7, 9, 14, 15.
 Chief uses of timber, 277.
Chionaspis salicis, 195, 227.
 Chloride of mercury, impregnation with, 303, 304.
 " of zinc, impregnation with, 303, 304.
 Chromic acid, impregnation with, 306.
Chrysomelidae, 193, 209.
Chrysomyxa, fungi of genus, 237, 243, 247.
 Circular saws, 313.
 Classification of soil, 30.
 Clay soil, 31.
 Cleaning and weeding, 75, 233.
 Clearance, partial, 78, 82, 83.
 Clear-felling, 82, 83.
 Clearwing moths, 194, 221.
 Cleft timber, 316.
Clematis, damage by, 234.
Clerus formicarius, 186.
 Click-beetles, 193, 209.
 Climate, influence of, 33.
 Climatic and physical effects of wood-lands, 26.
 Clog-making wood, 279, 287.
 Coach-building timber, 279.
Coccidae, 195, 227.
 Cockchafers, 193, 206, 229.
Coleophora laricella, 194, 219, 231.
Coleoptera, 183, 188, 192.
Coleosporium, fungi of genus, 237, 243, 246.
 Collection of tree-seeds, 289.
 Colophony, 328.
 Colour of wood, 270.
 Commission on Afforestation (1908), Royal, 24.
 " Development (1910), *Preface*, p. v.
 Commissioners of Woods and Forests, 20.
 Committee on Forestry, Irish (1907), 24.
 " Scottish (1911), *Preface*, p. v.
 Commonage, 160.
 Compartments, subdivision of wood-lands into, 116-119.
 Composition of wood, chemical, 268.
 Compound interest and discount, tables of, 151-156.
 Conflagrations, 161.
 Conifer timber, chief uses of, 278.
 " trees (*Coniferae*), 5, 17, 267.
 Control-book, 138.
 Conversion cost of, 317.
 " of Coppice, 82.
 " of timber, 315-319.
Convolvulus, damage by, 234.
 Cooperage timber, 279, 316.
 Copper vitriol, impregnation with, 303, 404.
 Coppice, conversion of, 82.
 " regulation of annual fall in, 125.
 " renewal of, 79, 80.
 " simple, 42, 79, 80, 112, 113, 125.
 " with Standards, 42, 44, 79, 80, 112, 113, 125.
 Coppices, cutting of, 80-82, 280, 284, 286.
 " Oak, 286, 288.
 " sale of, 287.
 Copse-standards, felling of, 82.
 " selection of, 81.
 " thinning of, 76.
 Coral-spot disease, 236, 242.
 Cord of wood, 316.
 Corrosive sublimate, impregnation with, 303, 304.
 Corsican Pine, 18.
Cossidae, 194, 219.
Cossus ligniperda, 194, 219, 231.
 Cost of cutting and sorting coppices, 286.
 " of felling, trimming, and logging timber, 286.

- Cost of carting timber, 292.
 „ of converting timber, 317.
 „ of planting, 71.
 „ of wire-fencing, 167-169.
 Cracking of wood, 272.
 Creosote, impregnation with, 303, 304-306.
Cronartium, fungi of genus, 237, 243, 246.
 Crop-register, 126, 130.
 Crops of wood, description of, 131.
 „ „ measurement of whole, 96.
 Crossbills, damage by, 177, 180.
 Cross-cutting saws, 313.
 Crown-fires, 161.
 Crushing, resistance to, 273.
 Crutch Pine-beetle, 192, 198.
Cryptococcus fagi, 195, 227, 232.
Cryptorhynchus lapathi, 192, 205.
 Cubic contents of logs, tables of, 147-150.
 „ „ of timber, measurement of, 89, 91, 286.
 „ „ per acre, estimate of, 96.
Cupressineæ, 6, 19.
 Cup-shakes, 272.
Cupulifera, 5, 15.
Curculionidæ, 192, 201-206.
 Custom of trade in sawn timber, 316.
 Customary measurement of timber, 89.
 Cuts, planting with, 59.
 Cutting of coppice, 80.
 Cuttings, planting of, 59.
Cynipidæ, 194, 225.
Cynips, insects of genus, 194, 225.
 Cypress, 6, 19.
 Damage from fungi, 235-252.
 „ from inorganic causes, 253-260.
 „ from insects, 181-232.
 „ from railway sparks, 161.
Dasychira pudibunda, 193, 211, 230.
Dasyscypha calycina, 236, 240.
 Dean Forest Forestry School, 24.
 Decay in wounds and holes, 78, 250, 251, 273.
 „ of timber, 276, 299.
 Deer, damage by, 170-172.
 Defects in timber, 272.
 Density and weight of wood, 271.
 „ of timber-crops, 106, 107.
 Dependent kinds of trees, 39.
 Dépôts, storage-, 286.
 Depth of planting, 64.
 Destructive insects, 192-232.
 „ „ generation table of, 228.
 „ „ list of, 192.
 Development Act (1909), 25.
 „ Commission (1910), *Preface*, p. v.
 Diameter, measurement of, 94.
 Dibbling, 65, 67.
 „ of acorns, 58.
 Different forms of woodland crops, 42.
Diptera, 183, 187, 195, 225.
 Discount and interest, tables of, 151-156.
 Diseases of trees, 236, 253.
 Dissolving the sap of timber, 301.
 Distance for planting, 61.
 Dodder, damage by, 234.
 Dominant kinds of trees, 39.
 „ stems, 76.
 Dominated stems, 76.
 Double-notching, 66.
 Douglas Fir, 6, 18.
 Dragging of timber, 291.
 Drainage, 48, 73.
 Drifting of timber, 297.
 Drill-board, 57.
 „ -sowing, 55-57.
 Drought, damage by, 257.
 Dry distillation of wood, 323-327.
 Drying of Oak-bark, 289.
 „ winds, protection against, 257.
 „ wood artificially, 300, 301.
 Dry-rot, 251, 273, 276, 308.
 Dunes, planting of, 74.
 Durability of timber, 276, 299-309.
 Duramen, 269.
 Durmast Oak, 8.
 Early frosts, damage by, 255.
 Earthwork timber-slides, 294.
 Economic uses of woodlands, 26.
 Education in Forestry, 24.
 Elasticity in timber, 274.
Elateridæ, 193, 209.
 Electricity, impregnation by, 309.
 Elm, 4, 7, 9, 12, 16.
 „ natural regeneration of, 85.
 „ -bark beetle, 192, 195, 228.
 „ -blister *Aphis*, 227, 232.
 „ -gall „ 227.
 Enclosure, statute of (1482), 21.
 Engines, portable and traction, 292, 310.
 English law regarding timber, 41, 114.
 Epiphytes, damage by, 234.

- Estate sawmills, 311.
 „ work, impregnating wood for, 305.
 „ „ timber for, 279.
 Estimate of age of trees and timber-crops, 98.
 „ of cubic contents per acre, 96.
 Expansion of wood, 272.
 Explanatory note to working-plan, 132, 133.
 Extermination of beetles, 189.
 „ of moths, 190.
 Extraction of timber, 291-298.
 „ of tree-stumps, 284.
 Eyre of the Forest, 20.
 Faggotting, 287.
 Fallow-deer, damage by, 171.
 Falls, protective, 122.
 False *Acacia* (see "*Robinia*").
 Farm-stock, damage by, 165.
 Faustmann's formula, 143.
 Felling, best season for, 234.
 „ cost of, 286.
 „ direction, the general, 120.
 „ of coppice, 81, 280, 284.
 „ of timber, 280-285.
 „ plan, 124, 126-129, 132.
 „ series, formation of, 120.
 „ with axe alone, 280, 281.
 „ „ axe and saw, 280, 282.
 „ „ bill or billhook, 280.
 „ „ lever - appliances, 282, 283.
 Fencing, 166-169.
Fidonia piniaria, 194, 215, 231.
 Field-book, 131.
 Filling of blanks, 74.
 Finches, damage by, 177, 179.
 Fir, Common or Scots (see "*Scots Pine*").
 Fire, damage by, 164.
 „ -extinction, 162.
 „ -prevention, 162.
 „ -proofing of wood, 308, 309.
 Fires in woodlands, 160-164.
 Fires Act, Railway (1905), 161.
 Firewood, measurement of, 316.
 Fissibility of wood, 275.
 Fixation of shifting sand, 74.
 Fixing the annual fall, 123-129.
 Flexibility of timber, 274.
 Floating of timber, 297.
 Flooring, square of, 316.
 Flow of sap in trees, 28, 264, 269.
 Flumes, 296.
Fomes, fungi of genus, 237, 248-250.
 Forest Acts and Rules, 159.
 „ courts, 20.
 „ demon, 282.
 „ laws, 159.
 „ offences, 159.
 Forest of Dean Forestry School, 24.
 Forestry, instruction in, 24.
 „ Irish Committee on (1907), 24.
 „ Royal Commission on (1908), 24.
 „ Scottish Committee on (1911), 24.
Preface, p. v.
 Forests, 20.
 Formation of woodlands, 47.
 Form-factor, 92.
 Forms of woodland crops, 41.
 Formulæ for calculating value of woodlands, 142, 143.
 Frame-saws, 313, 314.
 Frost, damage by, 34, 53, 60, 254-257.
 „ -cracks or frost-shakes, 256, 272.
 Fungi, 235-252.
 „ chief disease - producing, 236-252, 273.
 „ life-history of, 235.
 Fungus diseases in nurseries, 60, 236, 237-239.
 „ „ in plantations and woods, 236, 239-252.
 Furniture, timber for, 279.
 Furze, 51.
 Future management, working-plan for, 130-138.
 Gall-aphis of Spruce, 195, 226, 232.
 „ -midges, 195, 225.
 „ -wasps, 194, 225.
 Game, damage by, 169, 177, 178.
 „ -coverts, 114.
 Garden-chafer, 193, 208, 229.
 Gean (see "*Cherry*").
 General characteristics of timber-crops, 39.
 Generation table of destructive insects, 228-232.
Geometridæ moths, 194, 214.
 Germination of seed, 37, 38, 54-56.
 Girdling of old trees, 77, 234, 269, 300.
 Girth, measurement of, 91, 94.
 „ rate of growth of, 99.
 Gnats or Gall-midges, 195, 225.
 Goat-moth, 194, 219, 231.
 Gorse, 51.

- Gradual clearance of parent trees, 82-85.
 Grain of wood, 269.
 Grape-mould fungus, 236, 239.
 Gravel, 31, 254.
 Grazing in woodlands, 329.
 Grease-banding with patent tar, 189, 191, 213.
 Green wood, weight, &c., of, 271, 300.
 Gregarious trees, 39.
 Ground-fire, 161.
 " -game, damage by, 172-174.
 " -vermin, damage by, 175-177.
 Groups, natural regeneration in, 82, 83.
 Grouse, damage by, 177, 178.
 Growing-stock, description of, 130-132.
 " in a working-circle, valuation of the, 141.
 " or wood-capital, 106, 108, 110.
 Growing wood-crops, measurement of, 96.
 " valuation of, 139-146.
 Growth in cubic contents, rate of, 98-103.
 " in girth, rate of, 95, 99.
 " in height, rate of, 92, 99.
 " of timber-crops, habits of, 39.
 " of a tree, 27, 29.
 Habits of growth in tree-crops, 39.
 Hail, damage by, 259.
 Half-balks, 315.
 " -winged insects (*Hemiptera*), 184, 195, 225.
 Handbills or billhooks, felling with, 280.
 Hand-sawing, 281.
 Hardness of wood, 275.
 Hardwoods, 276, 277.
 " technical uses of, 277-279.
 Hardy trees, 34, 256.
 Hares, damage by, 173.
 Harvesting of bark, 280, 287-289.
 " of timber and coppices, 280-289.
 " of tree-seeds, 289.
 Haskin's vulcanisation process, 302.
 Hawkeye machine, 284.
 Hazel-weevil, 192, 205, 229.
 Heart-shakes, 248, 272.
 Heartwood, 269.
 " -trees, 269.
 Heat, damage by, 257.
 Heather, clearance of, 51.
 Heavy rainfall, 258.
 Hedgerow-trees, bark from, 289.
 Height, measurement of, 92.
 " rate of growth in, 99.
Hemiptera, 184, 195, 225.
Heteroptera, 195, 225.
 Highwoods, 42, 44, 112, 114.
 " felling in, 282-236.
 " mixed, 40, 45.
 " pure, 40.
 " regulation of fall in, 120, 129.
 " renewal of, 79, 80, 82.
 History of British Forestry, 19-25.
 Hoar-frost, damage by, 259.
Homoptera, 195, 225.
 Honey-fungus, *Agaricus melleus*, 251.
 Honeysuckle, damage by, 234.
 Hop-dog moth, 193, 211, 230.
 " -poles, 287.
 Hops, damage by wild, 234.
 Hornbeam (*Carpinus*), 5, 6, 9, 14, 15.
 Hornet Clearwing-moth, 194, 221.
 Horse-Chestnut, 5, 6, 7, 12, 16.
 Horses, damage by, 165.
 House-building, timber for, 278.
 Human actions, protection against, 159.
Humus, 35, 234.
 Hurdle-making, 287.
Hybernia defoliaria, 194, 217, 231.
 Hydrochloric acid, damage by, 259.
 Hydrostatic pressure, impregnation under, 304.
Hylesinini, 192.
Hylesinus, insects of genus, 192, 196-198, 228.
Hylobius abietis, 192, 201, 229.
Hymenoptera, 183, 187, 194.
 Hypsometers, 92-94.
Hysterium (see "*Lophodermium*").
 Ice, damage by, 259.
Ichneumonidae, 187.
 Identification of broad-leaved trees from buds, 6.
 " of broad-leaved trees from flowers, 12.
 " of broad-leaved trees from fruits, 15.
 " of broad-leaved trees from leaves, 8.
 " of Conifers, 17.
 " of timber, 266, 270.
 Immersion, impregnation by, 300, 305.

- Imports of timber, &c., 25.
- Impregnation with antiseptics, 299, 303-309.
- Increment, or growth in cubic contents, 36, 98-103.
 - „ gauge (Pressler's borer), 100.
 - „ measurement of, 98-103.
 - „ normal, 106, 107.
- “Indicating percentage,” 102, 140.
- Industries, timber-consuming, 278.
- Influence of situation on tree-growth, 33.
 - „ of woodlands, climatic and physical, 26.
- Injurious influences in soil and atmosphere, 253-260.
 - „ insects, classification of, 183, 192.
 - „ „ damage by, 184.
 - „ „ extermination of, 189-191.
 - „ „ generation table of, 228-232.
 - „ „ natural checks upon, 185.
 - „ „ protection against, 188.
 - „ „ table of chief, 192.
- Inland sand, fixation of, 74.
- Insects into orders, classification of, 183.
 - „ life-history of, 181.
 - „ useful (predacious and parasitic), 186.
- Instruction in Forestry, 24.
- Interest and discount, tables of, 151-156.
 - „ rate of, 139, 144.
- Intermediate yield from thinnings, 143-145, 280.
- Irish Forestry Committee (1907), 24.
- Ivy, damage by, 234.
- Jack, common, 282.
- Janker, 291.
- Japanese Larch, 19.
- Justice Seat, 20.
- Kyan's preservative process, 303, 304.
- Lackey moth, 193, 212.
- Lamellicorn beetles, 193, 206.
- Larceny as to trees and woods, 159.
- Larch, 6, 18, 19.
 - „ -aphis, 195, 226, 227, 232.
- Larch-bark, 288, 289.
 - „ bark-beetle, 192, 200.
 - „ -canker, 236, 240.
 - „ leaf-mining moth, 194, 219, 231.
 - „ leaf-shedding disease, 236, 240.
 - „ plantations, grazing in, 329.
 - „ resin-tapping, 327.
 - „ -sawfly, 194, 224, 232.
 - „ -seed, extraction of, 290.
 - „ shoot-mining moth, 194, 219, 231.
- Late frosts, damage by, 255, 256.
- Law of the minimum, 30.
- Laws for the protection of trees and woodlands, 159.
- Layering, 59, 81.
- Lead-banding for girth measurement, 95.
- Leaf-beetles, 193, 209.
 - „ -blotch diseases, 236, 237, 243.
 - „ -canopy (see “Normal density”).
 - „ -gall aphids, Elm, 195, 227, 232.
 - „ -mining moths, 194, 219, 231.
 - „ „ weevils, 192, 205.
 - „ -mould, 35, 234.
 - „ -roller moths, 194, 216, 231.
 - „ -scurf diseases, 236, 237, 243.
 - „ -shedding diseases of Conifers, 236, 238, 239, 240, 260.
- Leaves, function of, 28.
- Legal protection of woodlands, 159.
- Leopard-moth, 194, 221, 231.
- Lepidoptera*, 183, 193, 210.
- Lever-appliances in felling timber, 282.
- Liber*, 269.
- Lichens, damage by, 234.
- Lifting of seedlings by frost, 256.
 - „ plants for transplanting, 60.
- Light, influence of, 35.
 - „ -demanding trees, 35.
- Lightning, damage by, 259.
- Lignification, 268.
- Lime-tree or Linden, 5, 7, 9, 13, 16.
- Limitation of Forests Act (1640), 20.
- Limy soil, 31.
- Lina*, insects of genus, 193, 209.
- Liparis*, moths of genus, 193, 212.
- Load of timber, 316.
- Loamy soil, 30, 31.
- Locust-tree (see “Robinia”).
- Logging of timber, 91, 286.
- Logs, measurement of, 89.
- Longevity of trees, 38.
- Longhorn beetles, 193, 208.
- Looper-moths or spanworms, 194, 214, 231.

- Lop and top, 91.
Lophodermium, fungi of genus, 236, 238, 239, 240, 260.
Lophyrus, insects of genus, 194, 222-224, 232.
 Lustre in wood, 269.
- Magna Charta*, 20.
 Main-roads for timber extraction, 119.
 Major and minor produce, 105, 230.
 Malicious injury to trees and woods, 159.
 Management of woodlands, 87-146.
 " scheme of (see "Working-plan").
 Manila shavings, 318.
 Manuring in nurseries, 55, 56.
 Map of stock, 130, 132.
 Maple, natural regeneration of, 85.
 " Common or Norway, 5, 6, 8, 12, 16.
 " Great (see "Sycamore").
 " leaf-blotch, 236, 243.
 Maps of woodlands, 130.
 Maritime Pine, resin-tapping, 327.
 Marking and texture of wood, 269.
 " -hammer, revolving, 286.
 " stems for thinning or felling, 77.
 Mature fall, 105, 280.
 Maturity of timber crops, 38.
 May-beetle, 193, 206.
 Mean age of timber crops, 98.
 Measurement of logs, 89.
 " of girth, 91, 94, 95.
 " of height, 92.
 " of increment, 98.
 " of sample plots, 95-97.
 " of standing trees, 91.
 " of timber-crops, 96.
 " of timber by railway companies, 293.
 Measuring-board, 92.
 Mechanical properties of timber, 273-277.
 Medullary rays in wood, 264.
Melampsora, fungi of genus, 236, 243.
Melamporella, fungi of genus, 237, 243, 245.
Melolontha, insects of genus, 193, 206, 229.
 Membrane-winged insects, 183, 194, 222.
 Men and human actions, protection against, 169.
Merulius lacrymans, 251, 273, 276, 308.
- Method of treatment, choice of, 112.
 Mice, damage by, 175.
 Midges, 195, 225.
 Mill-saws, different kinds of, 313-315.
 Mineral food of trees, 30.
 " substances in soil, 30.
 " in wood, 268.
 Minor produce, 105, 280.
 Mirror-hypsometer, 93.
 Mischief, protection against, 159.
 Mistletoe, damage by, 234.
 Mixed woods, 39, 40, 45.
 Moisture, relation of wood towards, 271, 272.
 Moths, destructive, 193, 210-222, 230.
 " extermination of, 190.
 Mottled Umber moth, 194, 216, 231.
 Mound-planting, 70.
 Musk-scented Willow longhorn, 193, 208, 230.
- Naked plants, planting with, 60, 64.
 Naphthalining, 306.
 National system of British Arboriculture, 21, 22, 77.
 Natural regeneration, 80, 82, 83-85.
Nectria, fungi of genus, 236, 242, 243.
Nematus, insects of genus, 194, 224, 232.
 Nesting-boxes for birds, 59, 178.
 Net returns for woods, calculation of, 142, 143.
 Night-moths (*Noctuidæ*), 193, 213, 231.
 Nitric acid, damage by, 259.
Noctua (Trachea) piniperda, 193, 213, 231.
 Non-inflammable wood, 308.
 Non-parasitic diseases, 253-260.
 Normal capital in wood, 106, 108-112, 141, 142.
 " condition in woodlands, 106, 108, 142.
 " condition of working-circles, 108.
 " density, 106, 107.
 " distribution of annual falls, 106, 107.
 " increment, 106.
 " succession of age-classes, 106.
 Notching, 65.
 Number of plants per acre, 52, 63.
 " of trees per acre, estimating, 96.
 Numbering-hammer, 286.
 Nun-moth, 193, 212.

- Nurseries, 53.
- Nursery pests, 59.
 - „ work, 53-60, 256.
- Nurses in plantations, 65, 75, 233, 256.
- Nutrition of trees, 29.
- Oak, 5, 8, 10, 14, 15.
 - „ bark-boring beetle, 192, 201.
 - „ -bark coppices, 81, 287, 288.
 - „ different qualities of, 288, 289.
 - „ harvesting and sale of, 288, 289.
 - „ barking of, 288.
 - „ leaf-mining weevil, 192, 205.
 - „ leaf-roller moth, 194, 216, 231.
 - „ natural regeneration of, 84.
 - „ -seedling fungus, 236, 238.
- Occasional falls, 82, 119.
- Old trees, stimulating the growth of, 253.
- Oil of turpentine, 328.
- Orchestes*, insects of genus, 192, 205, 209.
- Oregon Pine (see "Douglas Fir").
- „ Red Cedar (see "Red Cedar.")
- Orgyia antiqua*, 193, 213, 230.
- Ornamental properties of timber, 269.
 - „ woods and trees, valuation of, 141.
 - „ woods and trees, renewal of, 82, 83.
 - „ woods, stored coppice as, 114.
- Osier bark, 288.
 - „ -beetle, 193, 209.
 - „ -fungus, 245.
 - „ Gall-midges, 195, 225.
 - „ -holts, 43, 75, 81.
 - „ cutting of, 280, 285, 288.
- Outward appearance of timber, 269, 270.
- Over-thinning, effects of, 77.
- Overwood, 44.
- Owlet-moth, 193, 213, 231.
- Packing plants for transport, 60.
- Painting of wood, 300, 309.
- Pale Tussock moth, 193, 211, 230.
- Parasitic diseases, 235-252.
 - „ plants, damage by, 234.
- Park-trees, bark from, 289.
- Partial clearances in immature crops, 74, 78.
 - „ „ in mature crops, 82, 83.
- Patent tar, grease-banding with, 189, 191, 213.
- Percentage, Indicating, 102, 140.
 - „ of increment, 101.
- Peridermium*-stage of fungi, 237, 246.
- Periodic falls, 124, 126-29.
- Peziza*, fungi of genus, 236, 240.
- Phoma*, fungi of genus, 236, 241.
- Phratora vitelline*, 193, 209, 230.
- Phyllopertha horticola*, 193, 208, 229.
- Physical effect of woodlands, 26.
 - „ properties of soil, 31.
- Physiology of trees, 27-30.
- Phytophthora omnivora*, 236, 237.
- Pigeons, damage by, 177, 179.
- Pine, different kinds of, 5, 18.
 - „ natural regeneration of Scots, 85.
 - „ -bark beetles, 192, 199, 200, 228.
 - „ bark-blister, 237, 246.
 - „ Beauty moth, 193, 213, 231.
 - „ -beetles, 192, 196-205.
 - „ -bud *Tortrix*, 194, 218.
 - „ -cambial beetle, the black, 192, 198.
 - „ -canker fungus, 237, 248.
 - „ leaf-blister, 237, 246.
 - „ leaf-shedding disease, 236, 238, 260.
 - „ resin-gall *Tortrix*, 194, 218.
 - „ root-fungus, 237, 248.
 - „ -sawfly, 194, 222, 232.
 - „ -seed, collection and cleaning of, 290.
 - „ -shoot beetles, 192, 196-198.
 - „ shoot-twisting fungus, 236, 243.
 - „ „ moth, 194 217, 231.
 - „ spanworm, 194, 215.
 - „ stem-rot, 237, 248.
 - „ -weevils, 192, 201-205, 229.
- Pissodes*, insects of genus, 192, 203, 229.
- Pit-planting, 68.
- Pitwood timber, 145, 278, 317.
- Planks, 316.
- Planting and plantations, 47-74.
 - „ and sowing, 47, 80.
 - „ best distance in, 61.
 - „ best season for, 60.
 - „ different methods of, 63-71.
 - „ factors for successful, 48.
 - „ for shelter, 74.
 - „ on moorland, 72, 73.
 - „ on sand-dunes, 74.
 - „ on sea-coast, 74.
 - „ rate and cost of, 71-74.

- Planting, regularity in, 71.
 „ soil-preparation for, 48, 51, 73.
 Plant-lice, 195, 225, 232.
 Plants, package, transport, and storage of, 60.
 „ supply of, 52.
 Plashing, 81.
 Pneumatic pressure, impregnation under, 303, 305, 306.
Polyporus, fungi of genus, 237, 251, 273.
 Poplar, different kinds of, 5, 8, 11, 15, 17.
 „ -leaf beetle, 193, 209.
 „ -rust fungus, 236, 243.
 „ Longhorn beetles, 193, 208, 229, 230.
 „ weevil, 192, 205.
 Portable sawmills and steam-engines, 310, 311.
Porthesia chrysorrhœa, 193, 211.
 Potash burning, 328.
 Powell's saccharine process, 307.
 Predisposition to disease, 253.
 Predominating kinds of trees, 39.
 Premature seeding, 254.
 Present capital value of a timber-crop, 140.
 Preservation of timber, 299-309.
 Preservatives, superficial application of, 300, 309.
 Pressler's borer, 100.
 „ formula for percentage of girth-increment, 101.
 „ "indicating percentage," 102.
 Private contract, sales by, 286.
 Protection against destructive birds, 177-180.
 „ against farm-stock, game, and vermin, 165-177.
 „ against injuries from inorganic causes, 253-260.
 „ against injurious insects, 181-232.
 „ against men and human actions, 159.
 „ against weeds and parasitic plants, 233-252.
 „ of woodlands, 157-260.
 „ of young timber-crops, 166.
 Protective falls, 122.
 Pruning, 78.
 „ of nursery-plants, 55.
 „ -shears, 55.
 „ -tools, 79.
 Pure woods, 39, 40.
 Puss moth, 193, 210, 230.
 Pyroligneous acid, preparation of, 327.
 Quality of land, 131.
 „ of seed, testing the, 54.
 Quantity of seed for sowing, 38, 55-57.
 Quarter-balks, 315.
 „ -girth measurement, 89.
 Quartering of timber, 315.
 Rabbits, damage by, 80, 173.
 Rafting of timber, 297, 298.
 Railway Fires Act (1905), 161.
 „ -sleepers timber, 279, 317.
 „ transport of timber, 293.
 Rain, action of heavy, 258.
 Rainfall, influence of, 33.
 Rapid-ageing of timber 301, 309.
 Rate of growth, measurement of, 36, 98-103.
 „ of interest in Forestry, 139, 144.
 „ of planting, 71.
 Rating of woods and plantations, 140.
 Red Cedar, 6, 19, 268.
 „ -deer, damage by, 170.
 „ -rot, 237, 248, 251, 273.
 „ „ root-fungus, 237, 248, 254.
 „ Sawfly, 194, 223, 232.
 Regeneration, natural, 80, 82-85.
 Regenerative power, 36.
 Register of crops, 126, 130.
 Regularity in planting, 71.
 Renewal of shelter-belts, 82.
 „ of woodland crops, 79-85.
 Rentals or returns, permutation of, 151.
 Reproduction, artificial production and, 47, 79-82.
 Reproductive and regenerative power, 36.
 Resin, distillation of, 328.
 „ in timber, influence of, 277, 299.
 „ products of crude, 328.
 „ -ducts in wood of Conifers, 264, 265, 267.
 „ -tapping, 327.
Retinia, insects of genus, 194, 217, 218, 231.
 Revision of working-plan, 138.
 Revolving marking-hammer, 286.
Rhizina undulata, 236, 239.
Rhizoctonia violacea, 236, 239.

- Rhizophagus depressus*, 186.
Rhizotrogus solstitialis, 193, 208, 229.
Rhytisma acerinum, 236, 243.
Rights of user, 160.
Rind-galls, 272.
Ringing of old trees, 77, 234, 269, 300.
Ring-shakes, 248, 272.
Ripping-saws, 313.
Road timber-slides, 294.
Roads in woodlands, 116, 279.
,, timber transport on, 291.
Robinia or False Acacia, 8, 12, 13, 17.
Rodents, damage by, 172-177.
Roe-deer, damage by, 172.
Root-rot, 237, 248-252, 273.
,, -system, shape of, 36.
Rosellinia quercina, 236, 238.
Rosin, preparation of, 328.
Rot in timber, 273.
Rotation of woodland crops, 39, 109, 120.
,, the most profitable, 143.
Rowan or Mountain-Ash, 5, 8, 12, 13, 17.
Royal Commission on Afforestation (1908), 24.
Rueping's creosoting processes, 306.
Ruling kinds of trees, 39.
Rust-fungi, 236, 243-248.
Saccharisation of timber, 307.
Sale of Coppices, 287.
,, of firewood, 287, 316.
,, of timber, 286.
Salix (see "Willow").
Saltus, 41, 114.
Sample-plots, measurement of, 95.
,, -stems, selection of, 96.
,, -trees, measurement of, 90-96.
Sand-dunes, planting on, 74.
Sandy soil, 30, 31.
Sap, dissolving of, 301.
,, in trees, movement of, 28, 264, 269.
,, in wood, 271, 300.
,, substances contained in, 268.
Saperda, insects of genus, 193, 208, 229, 230.
Sapwood, 269.
,, -trees, 269.
Satin moth, 193, 213.
Sauth (see "Willow").
Sawdust, utilisation of, 318.
,, waste in, 315, 317.
Sawflies, 194, 222-224, 232.
Saw-horn beetles, 193, 208
Sawmills, 310-319.
,, cost of converting timber in, 317.
,, for estate purposes, 311.
,, movable, 310, 311.
Saws, hand-, 281.
,, mill-, 313-315.
Scaffolding, timber for, 279.
Scale insects, 195, 227, 232.
Scaptlings, dimensions of, 316.
Scarabæidæ, 193, 206.
Scheme of management (see "Working-plan").
Schizoneura ulmi, 195, 227, 232.
Sclerotinia Fuckeliana, 236, 239.
Scolytini, 192.
Scolytus destructor, 192, 195, 288.
,, *multistriatus*, 192.
Scorching, 60, 257, 258.
Scots law regarding timber, 42, 114, 263.
,, Pine (see "Pine").
,, " natural regeneration of, 85.
,, Plane (see "Sycamore").
Scottish Forestry Committee, *Preface*.
Scribe, the, 77.
Sea-coast, planting near the, 74.
Season for felling, best, 284.
Seasoning of Oak-bark, 239.
,, of timber, 299-303.
Seed-bed, preparation of, 54.
,, sowing on, 55.
,, -collection, 54, 289.
,, -distributor, 53.
,, -extraction, 290.
,, for sowing, quantity of, 38, 55-57.
,, -kilns, 290.
,, -production, 37.
,, -tests, 54.
Seedling-pricker, 59.
Selection - fellings (see "Occasional falls").
Selection of sample-stems, 96.
,, of trees for planting, 115.
Senilising of timber, 309.
Septoria parasitica, 227, 236, 241.
Service-tree, 5, 8, 10, 13, 17.
Sesia apiformis (*Sesidiæ*), 194, 221.
Settled Lands Act (1882), 42, 114, 263.
Severances, 122.
Shade-enduring trees, 35.
,, influence of light and, 35.
Shakes in timber, 248, 272.
Shearing, resistance to, 274.
Sheep, damage by, 165.
Shelter-belts, 74, 82.

- Shelter for planting, 74.
 „ planting for, 74.
 Shifting sand, planting on, 74.
 Shipbuilding timber, 278.
 Shoot-boring moth, the Larch, 194, 219, 231.
 Shooting of timber, 293-296.
 Shoot-twisting fungus, the Pine, 236, 243.
 „ moth, 194, 217, 231.
 Shrinkage in wood, 272.
 Side-pressure, resistance to, 274.
 Silver Fir, 5, 18.
 „ bark, 288.
 „ canker, 237, 245.
 „ needle-blight, 236, 241.
 „ resin, 328.
 Simultaneous natural regeneration, 82, 84.
Sirex, insects of genus, 194, 225.
Siricidae, 194, 224.
 Situation, influence of, 33, 34.
 Skip-jacks, 193, 209.
 Slabs, waste in, 317.
 Sledging, 293.
 Sleepers, railway, 317.
 Sliding or shooting of timber, 293-296.
 Slips, planting of, 59.
 Slit-planting, 65.
 Slugs and snails in nurseries, 59.
 Smoke, damage by, 259.
 Snouted weevils, 192, 201-206.
 Snow, damage by, 258.
 Soda process for cellulose, 321.
 Softwoods, 276, 277.
 „ technical uses of, 277-279.
 Soil, classification of, 30.
 „ and situation, description of, 131.
 „ „ diseases due to unsuitable, 253-260.
 „ „ influence of, 33, 34.
 „ and subsoil, physical properties of, 31.
 „ -covering, removal of, 51.
 „ -moisture, 32.
 „ -preparation, 48, 51, 73, 74.
 „ -temperature, 33.
 „ „ influence of woodlands on, 26.
 Sowing and planting, 47, 80.
 „ of tree-seeds, 54-58.
 „ -horn, 58.
 Spades for planting, conical, 52, 53, 65, 69, 73.
 „ cylindrical, 69.
 Span-worm moths, 194, 214.
 Spanish or Sweet Chestnut, 5, 7, 9, 14, 15.
 Sparks, damage by railway, 160, 161.
 Specific gravity of wood, 271.
Sphærella laricina, 236, 240.
 Spinners (*Bombycidae*), 193, 210, 230.
 Splitting of wood, 272.
 Spokewood, 277.
 Sporadic trees, 39.
 Spruce *Aphis*, 195, 227.
 „ -bark, 288, 289.
 „ -bark canker, 236, 243.
 „ -gall *Aphis*, 195, 226, 227, 232.
 „ leaf-blister, 237, 247.
 „ moth, 193, 212.
 „ -needle rust, 237, 247.
 „ resin-tapping, 327.
 Spruces, 5, 18.
 Square of flooring, 316.
 „ of quarter-girth measurement, 89.
 Squares of timber, 315.
 Squirrels, damage by, 174.
 Stacked fuel, 316.
 Stag-headedness, 253.
 Standards in copse (see “Coppice with Standards”).
 „ thinning of, 76.
 Standing timber, sale of, 286.
 „ trees, bark-stripping of, 288.
 Statute of Enclosure (1482), 21.
 „ of Woods (1543), 21, 44.
 Steam-power sawmills, 310, 311, 313-315.
 Steaming of wood, 302.
 Stem-rot, 248.
Stereum hirsutum, 273.
 Stimulating the growth of old trees, 253.
 Stock-map, 130, 132.
 Stool-shoots, formation of, 37.
 Storage-depôts for timber, 286.
 „ of plants, 60.
 Stored coppice (see “Coppice with Standards”).
 „ coppice as game-coverts and ornamental woods, 114.
 Straight-winged insects, 184.
 Straining-posts in fences, 166, 169.
 Strength in timber, 273.
Strophosomus coryli, 192, 205, 229.
 Stump-extraction, 284.
 Stunted growth, 253.
 Subdivision of woodlands, 116.
 Subordinate kinds of trees, 39.
 Subsoil, 32.

- Succession Duty, valuation for, 141.
 Successive falls, natural regeneration by, 82, 83-85.
 Suckers, formation of, 37.
 Sulphate of copper, impregnation with, 304.
 Sulphurous acid, damage by, 259.
 Summer chafer, 193, 208, 229.
 Sun-burn or scorching, 60, 257, 258.
 Superficial application of preservatives, 300, 309.
 Supply of plants, 52.
 Suppressed stems, 76.
 Swainmote, 20.
 Sweet or Spanish Chestnut, 5, 7, 9, 14, 15.
 Sycamore, Great Maple, or Scots Plane, 5, 6, 8, 12, 16.
 „ leaf-blotch, 236, 243.
 „ natural regeneration of, 85.
 Sylva, the British, 1-19.
Sylva caedua, 41, 114.
 Sylvicultural characteristics of trees, 33-39.
 „ treatment, choice of, 42, 112.
 Sylviculture, 1-85.
 „ scientific foundations of, 27-33.
 System of Forestry, national British, 21, 22, 77.
 Tables of compound interest and discount, 151-156.
 „ of cubic contents of logs, 147-150.
Tachininae, 187.
 Tannic acid or tannin, 288.
 Tanning-bark, harvesting of, 287-289.
 Tarring of wood, 303.
 Technical uses of British timber, 277-279.
 Teeth of saws, 281, 314.
 Telegraph and telephone poles, timber for, 279.
 Telescope hypsometer, 94.
 Temperature, influence of, 33.
 Temporary nurseries, 53.
 Tender, sales by, 286.
 Tending of woodlands, 74-79.
 Tension, resistance to, 273.
Tenthredinidae, 194, 222.
Tetraneura ulmi, 227.
 Texture of wood, 269.
 Theft, 159.
 Thinning, 74, 75-78, 234, 280.
 Thinning, best rule for, 76.
 „ marking stems for, 77.
 „ of standards in copses, 76.
 Thinnings, yield from, 143, 280, 285.
Thuja gigantea (syn. *plicata*), 6, 19, 268.
 Timber, anatomical structure of, 264.
 „ average prices of, 279.
 „ felling of, 280, 285, 286.
 „ identification of, 266, 270.
 „ legal definition of, 41, 263.
 „ measurement of, 89-103.
 „ mechanical properties of, 273-277.
 „ ornamental properties of, 269.
 „ physical properties of, 270-273.
 „ practical uses of, 277-279.
 „ technical definition of, 263.
 „ properties of, 263-277.
 „ -Bob, 291.
 „ -calliper, 95.
 „ -carts and -waggon, 291.
 „ -consuming industries, 278.
 „ crops, estimate of age of, 98.
 „ „ measurement of, 96.
 „ „ rotation of, 39, 109, 120.
 „ „ selection of trees for, 115.
 „ -floating, 297.
 „ -jack, 282.
 „ -roads, 116, 282.
 „ -sales, 286.
 „ -sledges, 293.
 „ -slides, 293-296.
 „ -storage, 286.
 „ -tramways, 292.
 „ -transport, 291-298.
 „ „ by railway, 293.
 „ „ by road, 291, 293-296.
 „ „ by water, 297.
 „ -trees, British, 4.
 „ „ sylvicultural characteristics of British, 33-40.
 „ -valuation for succession duty, 141.
 „ -waggon, 291.
Tineidae, 194, 219.
 Top and lop, 91.
 Torsion, resistance to, 273.
Tortricidae, 194, 216.
Tortrix viridana, 194, 216, 231.
 Toughness of timber, 274.
Trachea piniperda, 193, 213, 231.
 Traction-engine, 291, 292, 310.
Trametes, fungi of genus, 237, 248.
 Tramways for timber-transport, 292.
 Transplanting of seedlings, 55, 57.

- Transplants, cost of, 57, 72.
 Transport of plants, 60.
 „ of timber, 291-298.
 Transverse pressure, resistance to, 273, 274.
 Tree-seeds, collection and extraction of, 289.
 „ -stumps, extraction of, 282.
 Trees, estimating the age of, 98.
 „ our woodland, 1-19.
 Trespass, 160.
Trichosphaeria parasitica, 236, 241.
 Trimming of coppice-stools, 81.
 „ of plants, 55.
 Turbines, 311.
 Turpentine, preparation of oil of, 328.
 Tussock moth, the Pale, 193, 211, 230.
 Twig-clusters, 245.
 „ -twister moths, 194, 216.
 Twisted fibre, 272.
 Umber moth, mottled, 194, 216, 230.
 Underplanting, 78, 234.
 Underwood, 44.
 Uniform natural regeneration, 82, 84.
 Universal wedge, 282.
 Unsoundness in timber, 273.
Uredinea, 236, 267, 243-248.
 User, rights of, 160.
 Uses of British timber, 277-279.
 Utilisation of woodland produce, 261-329.
 Valuation for rating, 140.
 „ for succession duty, 141.
 „ of timber-crops and woodlands, 139-146.
 Value of mature timber-crops and of thinnings, 139-146.
 „ of timber, market, 279.
 Vapourer moth, 193, 213, 230.
 Vegetable mould, 35, 234.
 „ parchment, 323.
 Vermin, damage by, 174-177, 181-232.
 Vertical notching, 65, 67.
 „ water-wheels, 311.
 Vigour of old trees, stimulating the, 253.
 Violet mixture, 239.
 Voles, damage by, 175-177.
 Vulcanisation of timber, 302.
 Waggon-timber, 279.
 Waggon transport, 291.
 Warping of wood, 272.
 Waste land, 25.
 Waste wood, utilisation of, 218.
 Water, relation of wood towards, 272.
 Waterlogging of land, 253.
 Water-power sawmills, 310, 311.
 „ -shoots, 296.
 „ -supplies, influence of woodlands on, 26.
 „ -wheels, vertical, 311.
 Wedge, the Universal, 282.
 Weeding in nurseries, 57.
 „ of plantations, 75, 233.
 Weevils, 192, 201-206.
 Weight of wood, 271.
 Wetness, damage by, 253.
 Whitebeam, 5, 8, 10, 13, 17.
 White-grub (see "Cockchafer").
 „ -piping in Oak, 273.
 „ -rot, 237, 250, 273.
 „ -scale, the felted, 195, 227, 232.
 Whortleberry, 51.
 Willow, different kinds of, 5, 7, 11, 15, 17.
 „ -bark, 288.
 „ -beetle, 193, 209, 230.
 „ -leaf fungus, 236, 237, 244.
 „ -longhorn beetle, 193, 208, 230.
 „ -rust fungi, 236, 237, 244.
 „ -scale, 195, 227.
 „ -weevil, 192, 205.
 Wind, damage by, 254.
 „ protection against, 120-123, 255.
 „ -screens or shelter-belts, 74.
 Windfall, 254.
 Winter frosts, damage by, 255.
 „ moth, 194, 214, 231.
 Wire-fences, erection and cost of, 166-169.
 Wireworms, 210, 230.
 Witches' brooms, 245.
 Wood, anatomical structure of, 264.
 „ -boring moths, 194, 219.
 „ „ bark-beetle, 192, 201.
 „ chemical composition of, 268.
 „ -consuming industries, 278.
 „ -demon, 282.
 „ Leopard-moth, 194, 221, 231.
 „ mechanical properties of, 273-277.
 „ physical properties of, 270-273.
 „ -pulp, preparation of, 319.
 „ -tar, 327.
 „ technical properties of, 263-279.
 „ -vinegar, 327.

- Wood-wasps, 194, 224.
 „ -wool, 318.
 Wooden timber-shoots, 295.
 Woodland crops, different forms of, 41.
 „ industries, 310-329.
 „ management, theoretical principles of, 104-129.
 „ produce, utilisation of, 261-329.
 „ products, 105, 280.
 „ sawmills, 310, 319.
 „ trees, 1-19.
 Woodlands and water-supplies, 26.
 „ artificial formation of, 47-74.
 „ capital value or productivity of, 139-146.
 „ climatic and physical effects of, 26.
 „ economic uses of, 26.
 „ in United Kingdom, 23-25.
 „ management of, 87-156.
 „ planting of, 47-74.
 „ protection of, 157-260.
 „ rating of, 140.
- Woodlands, renewal of, 79-85.
 „ tending of, 74-79.
 „ valuation of, 139-146.
 Woodmote, 20.
 Woods and plantations, 41.
 „ Statute of (1543), 21.
 Woodstock, Assize of (1184), 20.
 Working-circle, valuation of woods in a, 141.
 „ -circles, subdivision of woodlands into, 119, 120.
 „ -plan, 106, 130-138.
 „ „ examples of a simple, 128, 134, 136.
 „ „ explanatory note to a, 132, 133.
 „ „ formation of a, 130-138.
 Wound-rot and wound-surfaces, 272, 273.
 Wounds, antiseptic treatment of, 78.
 „ defects due to, 272.
- Yield tables, average, 97, 101.
- Zeuzera æsculi*, 194, 221, 231.

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