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NOTES  
ON  
THE UTILIZATION OF FORESTS,

BEING  
A COURSE OF LECTURES DELIVERED  
AT THE  
IMPERIAL FOREST SCHOOL, DEHRA DUN, INDIA,

BY  
E. E. FERNANDEZ,

DEPUTY DIRECTOR AND PROFESSOR OF FORESTRY AT THAT INSTITUTION.

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74 ILLUSTRATIONS.

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ROORKEE:  
PRINTED AT THE THOMASON CIVIL ENGINEERING COLLEGE PRESS.

1891.



# NOTES

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H M. ROBEEY, SUPERINTENDENT,

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## P R E F A C E.

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THE majority of our Students come to us with very imperfectly developed minds, and a totally insufficient knowledge of the English language. They are thus quite incapable of following with profit and taking down accurate notes of currently delivered lectures. This would be no great disadvantage if text-books of all the subjects taught were available; but as no such text-books existed, at least for the Forestry subjects, when the School began its work, the Instructors were constrained to adopt the extremely slow and painful method of dictating all the notes they wished to be taken down. The preparation of the necessary text-books was, and is still, therefore, an urgent want. At the risk of being considered presumptuous, the author has already published his class notes in several subjects, convinced that it was useless waiting for that happy day when he would enjoy the long and continuous leisure which the writing of an educational work demands. He claims once more the indulgence of the Indian Forest world in publishing the following pages, which contain, with no more revision than it was possible to give them as they were passing through the Press, his Notes on Forest Utilization dictated to the Senior Class of 1890-91. To secure for himself more time for revision, they were first printed by instalments in the "Indian Forester." Besides meeting the requirements of the Forest School, the publication of these Notes may, the Author earnestly hopes, serve another not less important purpose, *viz.*, that of offering, as it were, so many pegs on which to hang corrections and additional information which at present exists only scattered in the brains of foresters and others dispersed all over the empire.

Much help of this kind has already been most generously accorded by Messrs. C. W. Hope, A. E. Lowrie, and several other gentlemen. With the aid of such contributions from the wide experience of every one interested in Forestry it will be possible ultimately to prepare a complete Manual on the Utilization of our Indian Forests.

A work of this kind can of course never be an entirely original one. In the present instance, Karl Gayer's classic *Forstbenutzung* has furnished the general plan of the book, and also no inconsiderable portion of the subject-matter, and much valuable aid has been derived from several of Spons' encyclopædic publications, from Boppe's admirable *Technologie Forestière*, from Brandis' unrivalled *Forest Flora of North-West and Central India*, from Gamble's compendious *Manual of Indian Timbers*, from various published official papers, and last, though not least, from that treasury of forest lore, the pages of the *Indian Forester*.

E. E. FERNANDEZ.

FOREST SCHOOL, DEHRA DUN, }  
1st March, 1891. }

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# NOTES ON THE UTILIZATION OF FORESTS.

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## DEFINITION AND DIVISION OF THE SUBJECT.

In Forest Utilization, which is a composite art founded on the facts of special experience and the principles of general science, we study the most advantageous methods of collection, conversion and disposal of forest produce, consistent with the strictest rules of forest culture, the most complete satisfaction of our wants, and the securing of the highest possible profits.

The subject naturally divides itself into three main parts :—

- I.—Felling, collection, conversion, transport\* and disposal of wood;
- II.—Collection, preparation and disposal of minor produce; and
- III.—Minor forest industries.

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\* The subject of transport has very properly been transferred to the Course of Forest Engineering, and will be dealt with in the Special Manual on that Course.

# PART I.

---

## FELLING, COLLECTION, CONVERSION, AND DISPOSAL OF WOOD.

To be able to utilise a wood crop, we must first of all understand the technical properties of woods and the requirements of the various industries using wood as a raw product, such as carpentry, joinery, &c. Possessed of this knowledge, we must know how to fell, collect, convert and dispose of the wood. We thus have the following divisions of the subject of this Part:—

- I.—The technical properties of wood.
  - II.—Wood-using industries.
  - III.—Felling and conversion.
  - IV.—Disposal and sale of wood in the forest.
  - V.—Management of wood depôts and timber yards.
- 

### CHAPTER I.—TECHNICAL PROPERTIES OF WOODS.

The growth and structure of wood have been already studied in detail in the class of vegetable morphology and physiology. There is, therefore, no need to repeat old facts here, even to the slight extent that concerns the present subject. This amount of previous knowledge being assumed, those properties of woods will now be studied on which their utility and the manner of their employment depends. These properties are—

- I.—Relative form and size of the main parts of a tree—  
stems, branches and roots ;
- II.—Weight ;
- III.—Hardness ;
- IV.—Flexibility and elasticity ;
- V.—Aptitude for fission ;
- VI.—Strength ;
- VII.—Loss and gain of moisture and consequent contraction  
and expansion ; seasoning, warping and tendency to  
split and crack.
- VIII.—Durability ;
- IX.—Combustibility and heating power ; and
- X.—Defects and unsoundness.



## SECTION I.—RELATIVE FORM AND SIZE OF THE MAIN PARTS OF THE TREE.

The main causes of differences in these attributes are—

- (i). *Species*.—In the firs and deodar the stem extends right up to the highest point of the tree, and the branches have a comparatively slight development, especially in the case of firs, which possess branchlets rather than branches. Pines and some broad-leaved species, such as teak, simal, resemble firs and deodar up to a certain age; then a true crown, including little or no part of the stem, is formed. All other broad-leaved species (by far the largest majority of them) develop a distinct crown in middle age, many even earlier, especially when growing isolated.
- (ii). *Density and relative height of surrounding leaf-canopy*.—It is a universal rule that the denser and taller the leaf-canopy is in which a tree has grown, the larger is the proportion of stem in the tree; and the smaller, in the same measure, the proportion of branch wood, and some times also the mass of wood in the roots. These results are most marked in the case of broad-leaved species. Some large broad-leaved species, such as the mango, if grown isolated, branch only a few feet from the ground, and the old trees thus consist of a thick short stem dividing into massive, more or less horizontal boughs. Such trees are often, if not generally, shade-enduring. There are several shade-avoiding species, which develop a conspicuously long stem even in complete isolation, e.g., *Hardwickia binata*, teak, *Dalbergia Sissu*, *Adina cordifolia*, &c.
- (iii). *Age*.—In a canopied crop the topplings at first considerably exceed the quantity of material in the timber portion of the stem. In middle age the proportion of this latter is already very large, and goes on increasing, so that when the trees are large enough to be exploitable the branch wood may constitute only from 8 to 10 per cent. of the entire felled material. It is obvious that the quantity of wood in the roots goes on steadily increasing with age.
- (iv). *Soil and locality*.—It is a fact proved by universal experience that the proportion of wood in the stem increases with the favourable character of the soil and locality,

whereas the reverse is usually the case in respect of the root portion of the tree.

*General.*—It is thus evident that owing to the numerous and extremely variable factors which influence the relative development of the roots, stem and branches, it is impossible to arrive at any constant figures, even for trees in one and the same crop. This is especially true in India, where the same tree has often so wide a horizontal as well as vertical distribution. Nevertheless, it would be interesting to start experimental measurements throughout the Empire in order to obtain average figures for our principal species according to well-defined forest regions. A few figures taken from experiments made in Germany will be instructive. The following were obtained by Pfeil and Theodor Hartig in canopied high forest :—

Species.	Timber in trunk.	Branches and toppings.	Wood in roots.	Remarks.
	%	%	%	
Spruce, ..	80-85	8-10	15-25	} Both species with open foliage. Crown dense and spreading.
Silver fir, ..	80-85	8-10	15-30	
Scotch pine,	72-75	8-15	15-20	
Aspen, ..	75-80	5-10	5-10	
Birch, ..	75-80	5-10	5-12	
Beech, ..	60-65	10-20	20-25	
Oak, ..	60	15-25	20-25	

In stored coppice, Lauprecht obtained the following percentages for the branch-wood yielded by the stores:—

		50-60 years old.	60-100 years old.	Over 100 years old.
Aspen,	...	40	40	25-29
Birch,	...	35-40	35-44	34-40
Beech,	...	59-60	51	28-40
Oak,	...	58	42	18-25

Since the bole is usually the most important element of production in a forest, its shape and other attributes are obviously matters of the first importance. We shall, therefore, here specially study these attributes. For the stem of a tree to possess its maximum utility, it should be of the largest dimensions attainable, and it should be straight, free from branches, and as cylindrical as possible.

(a). *Dimensions.*—The height which a given species can attain depends principally on the suitability of the soil and locality, and most of all on the depth of the soil and the amount of moisture in it. A sufficient density of the leaf-canopy during the stage of

rapid elongation is also an important factor. For one and the same age, the diameter will, besides being influenced by the soil and the locality, be proportionate to the amount of lateral-growing room afforded to the crown and the roots when the stage of rapid lateral expansion has set in. This generally precedes by a certain interval the close of the stage of rapid elongation. Hence as regards both dimensions we shall obtain the best results by keeping the leaf-canopy as close as practicable up to the middle age of the crop, when the upward growth has begun to relax, and thereafter by opening it out in proportion to the requirements of the trees.

(b). *Straightness*.—The stem may form (i) a continuous line, or (ii) be contorted or present several angles. In the first case it may be straight or curved. If curved, it will be straight in one plane. Such are the crooks and knees of ships, felloes of wheels, &c. Some trees, such as deodar, the firs, *Bombax malabaricum*, &c., form a perfectly straight bole, whether they grow isolated or in the midst of a leaf-canopy; but the rest, which include pines and nearly all broad-leaved species, will grow up straight, only in fully canopied forests, and will even then fall behind deodar and the firs. The soil and the locality, especially depth of soil and the amount of moisture in it, are not without influence on the straight growth of the stem.

(c). *Freedom from branches*.—When the lower branches become sufficiently overshadowed by the development of the crown above, they gradually sicken, and die and fall off before they can attain any size, and leave behind knots or permanent scars in the wood of the trunk at their point of attachment. This process is of course accelerated by the presence of a surrounding leaf-canopy, which should, if the fullest advantage is to be derived from it, be continued during the entire period of upward growth, *i.e.*, from the thicket stage to the close of the high pole stage. Thenceforward the opening out of the leaf-canopy, unless it is carried to the point of more or less complete isolation, has no harmful effect on the bole. If the trees are isolated, epicorms may of course appear and render knotty the rings of wood formed thereafter. The strength and abundance of the epicorms will be in direct proportion to the unfavourable nature of the soil and locality for the growth of the species concerned and the unhealthiness or want of vigour of the crown, and in inverse proportion to the age of the trees.

Some species form a more or less long bole even in complete isolation, and are never branched low down even at an early age,

as *Hardwickia binata*; while others, at the extreme end of the scale, like deodar in certain localities and when completely exposed on every slide, remain branched right down to the ground during their whole life-time.

(d). *A cylindrical shape*.—It is obvious that the general usefulness of the stem is in direct proportion to its approach to a cylindrical form. The combined length and upper diameter of a log offer a much safer criterion of value than the mere cubical contents, or the combined length and mean diameter.

Some trees have eccentric or fluted growth. What the causes are, have not yet been fully ascertained. It is certain that the species to which the tree belongs, and the degree of isolation in which it has grown, have a great deal to do with it. The presence of a few large boughs produces an undue width of the concentric rings of wood along the vertical line leading down from each, whereas a tree that has a continuous stem extending up to its summit, and only small but numerous branches distributed all round is placed in the best conditions possible to develop a cylindrical bole.

A conical shape is favoured by growth out in the open. The crown coming down half way, if not lower, the inferior portion of the trunk is thoroughly well nourished, and the concentric layers of wood formed there are at least as thick as they are higher up; the consequence being the maintenance, and, owing to the growth of the main roots, even the more decided formation, of a conical outline. On the other hand, when a tree has been growing continuously in the midst of a leaf-canopy, the crown is high above the ground, and therefore the inferior portion of the bole is less well nourished than the portion above, the consequence being that the concentric layers of wood are thicker above than below, and the shape of the bole, from being originally conical, becomes more cylindrical every year.

The extent to which the shape of the bole departs from the true cylinder is usually, and with very great convenience, expressed by a factor, which, used as a co-efficient with the solid contents of a cylinder having the same circumference as the girth of the tree at breast-height, gives the true contents of the bole. This co-efficient, which may be termed the form co-efficient or factor, is obviously the ratio between the true contents and the contents of the ideal cylinder in question. In practice it is obtained by measuring a sufficient number of type trees taken from a given class of forest, and representing a given species and a given age or size class. The mean of these measurements is used and the mean co-efficient

calculated from it serves to give at once pretty accurately the quantity of timber in any number of trees of that species and age or size class, if we know their several girths at breast-height and the respective lengths of their boles.

## SECTION II.—WEIGHT.

Weight as a quality of wood affecting its employment is usually of only slight importance. Generally speaking, it need be considered only in the case of superstructures when extra strong supports would be very expensive, and in that of portable articles. But although of itself weight does not always possess much intrinsic importance, it nevertheless merits careful consideration, in that many other qualities of the first moment, such as hardness, durability, combustibility and heating power, swelling and shrinking with varying quantities of moisture, &c., are intimately connected with it.

The substance proper of all woods is slightly heavier than water, and its weight does not differ much for the different species. As a rule, it is heavier in conifers than in broad-leaved trees, amongst which the hardest and absolutely heaviest stand more frequently the lowest. It is heavier in young than in old trees.

The main cause of difference in the absolute weight of woods is their anatomical structure. The experiments of Theodor Hartig have established for the European woods the following percentages for the space occupied respectively by the solid wood-substance and the water and air contained in the tissues:—

	Wood substance.	Water.	Air.
The hard woods,	... 44·1	24·7	31·2
The soft woods, including conifers,...	27·0	33·5-31·7	39·5-40·4

For our hardest Indian woods, such as *Hardwickia binata*, iron wood, ebony, &c., we may safely assume at least 50 per cent. as the proportionate space occupied by the solid substance of the wood, the amount of air-space diminishing in almost equal measure.

The denser tissue of the exterior zone of a concentric ring is obviously heavier than the more or less porous tissue of the interior zone. From this it follows (*a*), that in conifers, in which class of trees, as an almost invariable rule, the width of the outer zone remains practically constant, while increase in rapidity of growth bears entirely on the inner zone, the weight of the wood is generally inversely proportional to rapidity of growth; (*b*), that in broad-leaved species, in which the largest and most numerous

pores are found in the inner zone, the weight of the wood is, on the contrary, directly proportional to rapidity of growth, since this last bears entirely on the outer zone; and (c), that in all other woods the rate of growth has no influence on the weight of the wood produced in one and the same soil and locality. These rules have, however, to be accepted with some slight reservations, to be presently explained.

What has been said in the preceding paragraph is of course true only when the anatomical structure of the specimens of wood compared is in every other respect the same. But large differences in weight may be caused by different thicknesses and degrees of solidity of the cell-wall, or in consequence of an abnormally slight or great development of the inner or outer zones. So that a narrow-ringed piece of conifer wood or a broad-ringed piece of oak or teak may nevertheless be lighter respectively than a broader-ringed piece of the same species of conifer or a narrower ringed piece of oak or teak. But it is in the case of woods in which the pores are uniformly distributed that the thickness and solidity of the cell-walls exercise the most considerable influence on their absolute weight.

But the relative widths of the interior and exterior zones, the absolute width of the entire concentric ring itself, and the thickness and solidity of the cell-walls and fulness of the cells, are themselves merely effects of which the nature and suitability of the soil and locality, and the degree of closeness of the surrounding leaf-canopy, are the causes. These causes are often so powerful, that they may reverse altogether conclusions based on the width of the concentric rings, especially in the case of specimens of wood in which the rings are unusually broad or unusually narrow. In the case of each species, heavy (and also really good) wood is, as a rule, produced in a soil of the proper mineral composition and containing the necessary quantity of moisture, provided that the requisite amount of warmth and light never fails. Where these conditions are wanting, or do not work harmoniously together for the species in question, especially if light is insufficient, the wood tends to become loose-tissued and light. The great influence of light in determining the weight of the wood is unquestioned in respect of solitary and canopy-grown trees. In respect of wood coming from different regions, where the power of the sun's rays is different during the season of vegetation, that influence is proved by the following figures, which have been calculated from data taken from Gamble's *Manual of Indian Timbers*—data which, if not scientifically accurate, are nevertheless sufficiently so for our purpose :—

		<i>Sun less powerful.</i>		<i>Sun more powerful.</i>	
		Average weight of cubic foot	Number of experiments.	Average weight of cubic foot.	Number of experiments.
<i>Bombax malabaricum,</i>	...	22.3	6	31.5	2
Teak,	... ..	38.4	131	43.7	43
<i>Pinus longifolia,</i>	...	38.3	3	44	3
<i>Pinus excelsa,</i>	...	29.1	6	32.3	3
Sissu,	... ..	46.6	102	48.6	13
<i>Terminalia tomentosa,</i>	...	55.5	11	61.4	12
Sál,	... ..	57.3	209	61.6	27

As said before, the soil affects the weight of wood by the amount of moisture it contains, and by its mineral composition. Excess of moisture for any species in question tends to make the wood spongy. Where it prevails, added high temperature and bright illumination merely increase the width of the concentric rings, without at all increasing the weight of the wood. In the case of conifers growing in wet places, the wood may be extremely light in spite of narrow rings. The effect of the mineral composition of the soil on the nourishment of woody tissue is too well known to be repeated here. Even an abundance of moisture and free enjoyment of light may fail to produce dense wood in a soil that is poor in the mineral food of plants.

The general conclusion to be drawn from the three immediately preceding paragraphs is that the rule establishing a direct connection between the weight of a piece of wood and the width of the concentric rings composing it, may often be misleading, if these rings are unusually wide or unusually narrow, but generally holds good in all other cases.

The density of wood is influenced in a large measure also by the age of the tree. As said before, the wood substance formed by a young tree is heavier than what is produced by the same tree at a more advanced age, the difference sometimes exceeding 60 per cent. But it is also an established fact that all trees as a rule form heaviest wood in an absolute sense when young. Thus it is that in young trees there is usually no appreciable difference in weight between the heartwood and the adjacent sapwood; whereas the difference between the weight of this sapwood and that of heartwood formed in later years may be really appreciable. The word "may" is used advisedly, because, although in most species the heartwood is notably heavier than the sapwood, this assertion cannot be generalised into a rule, since the mere circumstance of a

difference in the width of the concentric rings, while it may accentuate the original greater weight of the heartwood, may also turn the scale in favour of the sapwood.

In all the foregoing remarks the quantity of water in the wood has been left out of account. In practice we distinguish three states of the wood after it has been felled—(1) when it has been *fresh-felled*, (2) when it has undergone some degree of seasoning before it is removed from the forest (we may use the term *forest-seasoned* in this case), and (3) when it has been *completely seasoned*, that is to say, has lost all the water it can part with under shelter in a dry atmosphere. Fresh-felled wood may for all practical purposes be assumed to contain 45 per cent. of water, while in completely seasoned wood the quantity of moisture varies from 15 to 20 per cent. The proportion of moisture in forest-seasoned wood is, of course, a very variable quantity.

According to Theodor Hartig's experiments the quantity of water in any wood depends on the species to which it belongs. As a rule, the conifers contain the largest quantity, and the hardest woods the least. There are, of course, exceptions to the rule. Thus alder, birch and poplar, all very soft woods, are amongst those which contain least water; while oak, sál and some other hard woods contain it in abundance. In the case of woods that are naturally impregnated with resins and oils, the difference between the green and seasoned weights is inversely proportional to the quantity of those substances in the wood. The more recently formed wood in a healthy growing tree contains more water than the older portions, and hence the sapwood and the wood in the crown are more full of moisture than the heartwood and the wood of the trunk respectively. Hartig's experiments, already referred to, apparently establish the remarkable fact that the quantity of moisture in the soil has no influence whatsoever on the amount of moisture in the wood of trees grown thereon; at any rate, there is no interdependence between them. Contrary to the general belief hitherto prevailing, every one of the European trees, which, like alder, oak and poplar, delight in wet and even watery soils, are conspicuous by the small quantity of moisture in their wood. Further research is, however, still necessary before any final conclusions can be drawn.

The wood of trees is more full of moisture during the season of rest than during the season of vegetation. Hence the green weight of wood depends also on the time of the year at which it is felled. But as the wood contains most reserve matter while the trees are resting, even the dry weight of wood is dependent on the season in which it is cut.



It is obvious, as said before, that resin and oils impregnating wood increase its dry weight. For this reason, in resiniferous trees the wood in the interior of the stem is heavier than the outside layers; and in conifers, the narrow-ringed wood of the branches, and in pines and deodar, also the resin-gorged wood of the roots, is heavier than the wood in other portions of the tree. In conifers the outer zone of each ring is richest in resin, and hence the broader-ringed a piece of conifer wood is, the smaller will, as a rule, be the proportion of resin in it, and consequently the less its weight. But besides resin and oils, wood may contain inorganic salts, such as calcium carbonate, potash, magnesia, &c., silex, and other substances, which add their own weight to that of the original substance of the wood. Long immersion in water, and especially floating, dissolves out these various substances and makes the wood very appreciably lighter.

In one and the same tree the weight of the wood is, as a rule, more or less different, according as it is taken from the roots, or from the lower or upper part of the stem, or from the centre of the stem, or from near the bark or from the branches. In the stem this difference is in a great measure due to a difference in the width of the concentric layers of wood and in the relative width of the inner and outer zones of those layers in its different portions. The wood of the branches is generally heavier than that of the stem, but in the case of small twigs there is, according to Nördlinger, very little difference even from species to species in the green weight of the wood, the figure for all species taken together ranging from 57 to 66 lbs. per solid cubic foot. The wood of the roots is the lightest of all. But from this general rule must be excepted (i) that of the crown of the roots, which is frequently remarkably heavy, and (ii) that of conifers producing resin in abundance, the wood of the roots of which sometimes weighs as much as 65 lbs. per cubic foot. According to Nördlinger the weight of the wood is, in all species, proportionate to the thickness of the roots from which it is taken.

Knotty growth, in whatever part of a tree it occurs, increases the weight of the wood. The new growth of wood surrounding or covering healthy wounds is also heavy.

For convenience sake we may establish six classes or degrees as follows in respect of weight:—

I. *Extremely heavy*.—Average weight of cubic foot = 70 lbs. and upwards.

*Hardwickia binata*, ebony, *Pterocarpus santalinus*, *Mesua ferrea*.

II. *Very heavy*.—Average weight of cubic foot = over 60 and up to 70 lbs.

Sál, sundri, iron-wood, khair, sandal-wood, *Terminalia tomentosa*.

III. *Heavy*.—Average weight of cubic foot = over 50 and up to 60 lbs.

Sissu, black-wood, satin-wood, babul, box, *Pterocarpus Marsupium* and *indicus* (Padouk).

IV. *Moderately heavy*.—Average weight of cubic foot = over 40 and up to 50 lbs.

*Schima Wallichii*, mango, *Hopea odorata*, *Anthocephalus Cadamba*, walnut, haldu, teak, mahogany, *Lagerströmia Flos-Reginæ*, jack.

V. *Light*.—Average weight of cubic foot = over 30 and up to 40 lbs.

*Michelia Champaca* and *excelsa*, toon, *Gmelina arborea*, *Pinus longifolia* and *excelsa*, deodar, poplar, willows.

VI. *Very light*.—Average weight of cubic foot = 30 lbs. and under. Simal, *Sterculias*, *Ailantus excelsa*.

### SECTION III.—HARDNESS.

In respect of any wood we may say that its hardness is the resistance it offers to penetration by another body.

It is evident that this resistance is an entirely relative term, and will be different not only according to the shape and nature of the penetrating body (whether it is a point or edge, or a blunt projection, and so on), and the manner in which it is forced against the wood (whether by impact or by mere constant pressure, &c.), but also according to the direction in which, with reference to the grain of the wood, the penetrating body is moved. The direction may be (i), parallel to the fibres, or (ii), at right angles to them, or (iii), oblique to them. In the first case the penetrating body may be applied along, or at right angles to, the medullary plates. In all three cases the resistance will be different according as the body is forced into the wood on a longitudinal or on a transverse section.

Whatever the direction in which penetration is attempted into the wood, the resistance will depend on five several circumstances as follows:—

(a). *The structure of the wood*.—In the first place, hardness will depend on the coherence with each other of the component elements of the wood; and for the same degree of cohesion, the closer together the fibres are, that is to say, the denser, or, in other words, the heavier the wood is, the harder will it be. Lastly, anastomosis and a wavy course of the fibres increase hardness, while shortness of the fibres diminishes it.

(b). *Toughness of the fibres*.—Tough fibres yield under pressure without breaking; they merely undergo a certain amount

of displacement, which only brings the fibres closer together and increases the hardness of the wood at that point. Porous woods offer most room for this displacement of the fibres, and, other circumstances being the same, possess the greatest degree of resistance. The hardness due to toughness of the fibres manifests itself most in a direction transverse to that in which they run.

(c). *The quantity of moisture present.*—Dry wood is harder than green wood, firstly, because moisture softens the tissues, and next, because green wood, being swollen up with moisture, occupies for the same amount of solid matter, more space than dry wood. The superior hardness in the dry state is more conspicuous, the heavier the wood is. Dry *Hardwickia binata* and ebony are as hard as horn. In the case of very light tough woods, such as willows, poplar, semal, &c., since the degree of toughness is in proportion to the amount of contained moisture, the influence of moisture on hardness becomes inconsiderable. The heartwood, owing to the smaller quantity of water it contains, is always harder than the sapwood, even when their respective weights are not very different; and for the same reason the older parts of a tree, provided of course they are still sound, are heavier than those which are younger.

(d). *The quantity of resin and oil present.*—Oil makes the fibres tougher and fills up the interstices. In resinous woods, however, hardness is in inverse proportion to the quantity of essential oil present, since the oil keeps the resin in a soft condition. Wood in which the resin is quite dry, as in stumps of deodar and pine trees felled sometime ago, is almost as hard as horn.

(e). *The tool with which penetration is attempted.*—The resistance will be different according as we use a gimlet, or a file, or a plane, or a saw, or a chisel, or sand paper, &c. Thus old posts, exposed during years to every weather influence, of *Hardwickia binata*, khair and other woods that do not decay from exposure, will defy all efforts to drive nails and bore holes into them, but will nevertheless be easily cut up with a saw. We as foresters need consider only the resistance offered to the axe and saw.

In respect to the axe the greatest resistance to be overcome is *across* the fibres, the least *parallel* to the fibres, especially in the direction of the medullary plates and along the concentric rings of growth, when these are well-marked. The resistance to be overcome parallel to the fibres is connected with aptitude for fission, and will, therefore, not be considered here. From what has gone before, it will have been seen that the resistance offered to an axe driven across the fibres, whether perpendicularly or obliquely,

depends on the closeness of texture of the wood, the toughness length and tendency to twist or anastomose of the fibres, and the quantity of moisture present. It will hence be understood why light wood with tough fibres requires a heavier axe than heavy wood with short fibres. The axe not only cuts but also presses, and tough loose fibres give before the passage of the axe, being merely pushed forward. In every case the resistance offered to the axe is greatest at right angles to the fibres, and diminishes in proportion to the obliqueness of the stroke.

The resistance offered to the saw does not resemble at all that offered to the axe. Contrary to what happens in the case of the axe, for most species, especially those which are light and tough, the resistance is greatest in the direction of the fibres, since the saw has no splitting action, but takes off a string of fibres, shred by shred, whether cutting along the fibre or across it. The teeth of a saw work principally by tearing, very little, sometimes, as in wood of loose texture, not at all, by a shaving or cutting action. Hence the tougher and longer the fibres are, and the looser the structure of the wood, the more difficult is the work of the saw, for the teeth then no longer break up or divide the individual fibres, but tear them asunder from one another, owing to which circumstance the sides of the cut become rough and uneven, a large quantity of coarse sawdust is produced, and the saw has to overcome a very great amount of friction. In the case of wood of compact texture and possessing short and closely-cohering fibres, the fibres are more easily broken or otherwise divided, the sides of the cut are smoother and the sawdust finer and less abundant. It is thus a general rule that amongst broad-leaved species the heavier and denser kinds are the easiest to saw. Resin and other glutinous secretions clog the teeth of the saw, and increase very considerably the friction. Nevertheless, the conifers, although also loose tissue, are easy to saw because of their extremely regular structure. As a rule, green wood is easier to saw than dry wood, since, as we have seen above, moisture renders wood softer, although the fibres themselves become less brittle. The only exceptions to this rule are woods with very loose texture and long tough fibres, which are rendered all the tougher and stronger by the moisture.

According to Gayer, if we denote the resistance offered by recently-felled beech to cross-cutting with the saw by unity, the corresponding resistances offered by other species are—spruce = 0.60, Scotch pine = 0.67, silver fir = 0.76, larch = 0.93, oak and aspen = 1.09, alder = 1.10, birch = 1.35, willow = 1.37, lime or linden = 1.77.

## SECTION IV.—FLEXIBILITY AND ELASTICITY.

We understand by flexibility the capability of being bent out of shape without any kind of rupture of the component wood elements. Elasticity in addition to flexibility implies a return, more or less complete, to the original shape, that is to say, the resumption of their original relative positions by the elements. Thus mere flexibility and elasticity, although closely inter-connected up to a certain point, are different properties. Both agree in requiring the fibres to be more or less extensible and to play upon one another; and for this reason they both require the fibres to be long and straight and parallel, and the wood to be homogeneous. In the case of woods with distinct concentric rings, both properties are heightened by narrowness of the rings, which form thin plates capable of moving one upon another like the leaves of a book.

**FLEXIBILITY.**—Mere flexibility without elasticity is favoured by a wet condition of the fibres, the walls of which are then soft enough to stretch and change shape easily. Hence steaming under a high pressure, or which nearly comes to the same thing, exposure in a green state to a temperature sufficient to form steam, gives wood its maximum of flexibility. As a rule, light woods are more flexible than heavy woods, because their looser structure gives more room for the play of the fibres upon one another, and enable them to become soaked with moisture more easily and completely. Hence the wood of the roots is more flexible than that of the stem, which itself is, with few exceptions, more flexible than that of the branches. For the same reason, and also because it contains more moisture, sapwood is more flexible than heartwood, and the outer concentric rings than those further in the interior. The wood of trees grown in wet soils is often more pliable than the wood of trees grown on dry soils. For one and the same species young stool-shoots are more flexible than seedlings of the same size. The wood of climbers is the most flexible of all, being very straight and long-fibred and of loose texture.

Flexible wood is used for band boxes, drums, frames for sieves, hoops, wicker work, matting (bamboos and canes), wattling, withies, bentwood furniture, &c. Wood that has been made flexible artificially, loses all its flexibility and becomes very brittle, once it is dry.

**ELASTICITY.**—Moisture diminishes elasticity, only dry (but not too dry) or moderately green wood being elastic. For one and the same species weight always increases elasticity. Hence well-nourished wood is more elastic than wood of loose texture, the

wood of the stem than the more porous wood of the roots, slow-grown conifer wood than faster-grown specimens, and so on. Elasticity is increased by slow seasoning; hence killing a tree by girdling is injurious to elasticity.

The following scale of elasticity may be adopted:—

1. Extremely elastic—bamboos, canes.
2. Very elastic—Grewias, sundri, *Anogeissus latifolia*.
3. Elastic—*Diospyros* spp., sissu.
4. Pretty elastic—teak, mango, tun.
5. Slightly elastic—deodar, *Hardwickia binata*, semal.
6. Very slightly elastic—*Boswellia serrata*, silver fir.

#### SECTION V.—APTITUDE FOR FISSION.

All woods are more or less fissile, *i.e.*, capable of being split down their whole length when a wedge is forcibly driven along between the fibres. The ease or difficulty with which a piece of wood can thus be split depends on five several circumstances as follows:—

I. *The structure of the wood.*—The straighter and longer and more parallel the fibres are, the more easily will the wood split, *e.g.*, bamboos, canes, conifers, teak, &c. Hence for one and the same species the faster-grown the specimen, the more easily will it split. All breaks of continuity of the fibres, such as knots, branches, and wound scars, increase the difficulty of splitting; in other words, canopy-grown trees with long, clean boles and a high restricted crown furnish the best wood for fission, and trees with low spreading crowns the worst. Wood from the branches and roots, being more knotty and crooked and twisted, is more difficult to split than the wood of the stem; and the most difficult of all to split is the wood in the region of the root-collum, from which all the main lateral roots of the tree take their rise. The medullary rays, by their thickness, length and depth, influence very conspicuously the aptitude of wood for fission, as all woods split most easily in the direction of the rays. Owing to the presence of large rays, woods, which like the oaks, would otherwise be extremely difficult to split, are among those most easily fissile. Great number, by forcing the fibres to extend evenly and straight, makes up for smallness and even minuteness of the rays, as in the case of the conifers. The degree of coherence between the fibres and the medullary plates also influences the fissility of a wood. The coherence between the concentric rings of wood is very much greater than that between the fibres and medullary plates. In old in-

dividuals of spruce and of some others of our species the concentric rings, however, separate easily.

II. *Flexibility and elasticity*.—It is obvious that elasticity increases aptitude for fission, since as the wedge is driven forward, the split extends by the force of the mere leverage exercised on the sides by the wedge, the cutting edge of which does no work at all once it has helped to introduce the tool into the wood. On the other hand, when mere flexibility exists, there can be no such leverage, and the entire work of parting the fibres has to be done throughout by the edge of the wedge. Mere flexibility helps fission only in so far that without it the wood on each side of the wedge would break off short.

III. *Contained moisture*.—As a rule, green wood can be split more easily than dry wood. Hence sapwood is easier to split than heartwood, and wood felled during great activity of the sap at the beginning of the season of vegetation than wood felled at any other season. This greater facility is due to the slighter degree of coherence between the fibres in a green state and to the greater flexibility, up to a certain limit, of the wood. We say up to a certain limit advisedly, for if this limit is exceeded, as in the case of extremely flexible woods, the difficulty of fission is increased (this clearly proves what has been said in the immediately preceding paragraph).

IV. *Frost*.—It is obvious that frost makes the fibres brittle.

V. *Resin and oils*.—Resin, by diminishing elasticity, renders fission difficult, while fixed oils generally facilitate it.

VI. *The circumstances under which the tree has grown up*.—Growth in the midst of a proper leaf-canopy and with a sufficient supply of moisture increases aptitude for fission by producing a uniform tissue composed of straight, long and parallel fibres not too closely connected together owing to a high degree of lignification. Since the same conditions favour diametral increment, wood with wide concentric rings is usually more easily fissile than wood with narrow rings. And generally speaking we may say that the wood of all vigorous individuals is easier to split than that of weak ones. Hence the well-known fact that young stool-shoots are much more easily split than seedlings of the same size. The wood of trees grown in hot, dry climates, as it is always so highly lignified, is more difficult to split than that of trees from temperate localities.

The ease or difficulty with which a wood can be split is a circumstance possessing considerable importance, since a great many industries depend on this quality of wood, especially the trade in

firewood. In what degree the wood of any individual of a given species is fissile can be easily recognised on the standing tree itself, which, to split well, ought to have a long, clean, straight, full and symmetrical bole, and a not too thick bark containing wide, long and straight cracks that have a tendency to extend upwards. The soil and locality also furnish indications. In the case of a felled tree, besides having the points already enumerated, we can also examine a small ribbon of the wood taken off with a plane. A crack, however small, through the centre on the transverse section is a certain proof of easy fissility. Woodmen have often to put up with the disagreeable experience of seeing a tree split up and fall before it is sufficiently cut through. Species whose individuals play this unpleasant trick are always easy to split.

As a beginning, and subject to numerous additions and corrections, we may establish the following classes for India according to aptitude for fission :—

1. Extremely fissile—bamboos, canes.
2. Easily fissile—teak, *Anogeissus latifolia*, deodar, tun, the firs.
3. Pretty fissile—mango, *Pterocarpus Marsupium*.
4. Difficult to split—sál, babul, *Terminalia tomentosa*.
5. Very difficult to split—*Terminalia bellerica*, *Boswellia serrata*.

#### SECTION VI.—STRENGTH.

By the term strength is understood the degree of resistance which a given kind of wood offers—(i), to being broken across the grain (*transverse strength*), or (ii), to crushing, or (iii), to being torn asunder by a shearing force, or (iv), to being twisted. In discussing the strength of woods the mathematical side of the question will not be touched upon, belonging, as it does, to the subject of practical mechanics.

I. *Transverse strength*.—For our purpose the resistance which wood offers against a transverse strain stands in the first place, for it is principally this resistance which has to be considered in all timber for roofing, scaffolding, floors, carriage building, ladders, &c. In a general way it may be said that the heavier the wood, the greater the transverse strength. But this general rule, although nearly always true for specimens of one and the same species, is subject to modification according to the structure of the wood and the cohesiveness of the fibres. Length and straightness of fibre and uniformity of texture contribute to transverse strength. Moreover, whatever increases elasticity and flexibility, increases also transverse strength. Great abundance of resin, especially in a dry condition, is a cause of weakness. In one and the same tree, pro-



vided of course that every part is sound, the transverse strength of the wood increases from inside outwards, and from below upwards, this increased strength being due mainly to greater uniformity of structure and length of fibre. The results of recent researches would show that wood felled during vegetative repose is, owing doubtless to the presence of reserve matter which increases the cohesiveness of the elements, stronger than wood felled during vegetative activity, especially at the first burst of such activity. Wood seasoned gradually is stronger than wood seasoned too quickly; hence killing a tree by girdling diminishes the strength of the wood. Combining the facts given in the two immediately preceding sentences, we have the inference that for India the rainy season, and then the cold weather, are the best time, irrespective of all other considerations, for the felling of timber trees.

II. *Resistance to crushing.*—This resistance is required in a high degree in wood for piles, posts and other uprights, wheel-spokes, &c. It is always in direct proportion to transverse strength and elasticity, since in nearly every case uprights that are overloaded finish up by bending and then breaking across the fibre. A consideration of resistance to crushing strains is of little practical utility, for on account of other reasons the dimensions of pieces of timber used as uprights are far in excess of the limits necessary for resistance to mere crushing.

III. *Resistance to shearing.*—This resistance is of importance only for woods used for a few special purposes, such as sunken piles, tent-pegs, chisel handles, &c. It is always greatest in the direction of the fibres. For one and the same species, it will be in direct proportion to the weight of the wood. For different species it will depend on the cohesion of the fibres and on the extent to which they are anastomosed. The *Terminalias*, and babul, khair and similar woods offer powerful resistance to shearing strains.

IV. *Resistance to torsion.*—This kind of strength is of even still less importance than the two preceding, as it is required for very few purposes (axles and axle-trees), and even then the dimensions of the pieces of timber used are, owing to other and entirely independent considerations, much in excess of what are absolutely necessary for overcoming torsion alone.

SECTION VII.—LOSS AND GAIN OF MOISTURE AND CONSEQUENT CONTRACTION AND EXPANSION. SEASONING, WARPING, AND TENDENCY TO CRACK AND SPLIT.

*Seasoning.*—Before a piece of wood can be used it must be air-

dried or seasoned, that is to say, it must have lost all the moisture it can part with under free exposure to air in the ordinary state. The quantity of moisture in fresh-cut wood depends on the season of felling, the portion of the tree from which it is derived, and the species to which it belongs.

The rapidity and completeness with which any piece of wood becomes seasoned depends on its structure, on the extent of surface it exposes to the air in proportion to its volume, on whether it is heart or sap wood, on whether it is barked or not, on the quantity of moisture it originally contains, and very largely on the condition of the air, especially as regards its humidity and movement. Porous woods season more quickly and more completely than woods with a close grain. The wood of all species parts with its moisture most quickly from a transverse section, and least so from a longitudinal section made at right angles to the medullary rays. Sapwood dries quicker than heartwood, and fresh cut wood sooner than wood that has been kept sometime and prevented from seasoning, moreover, wood loses its moisture most rapidly just after it has been cut, the rapidity diminishing in geometrical proportion with lapse of time. Wood that has been previously dried and then soaked in water dries more quickly and completely than wood that has been put into water green, and generally the original moisture of the wood is evaporated from it less slowly than the water it may take up after the tree has been felled; hence wood that has been floated or kept in water some time, or, which comes to the same thing, that has been constantly washed by heavy showers of rain, seasons more quickly and completely than wood allowed to season only under exposure to air. In a damp or cold atmosphere, seasoning is slower than in a dry or warm one, and very much slower in a close confined place than in one in which there is a free and active circulation of air. Steaming hastens seasoning, whereas impregnation with different solid substances retards it. The most completely seasoned wood always contains from 15 to 20 per cent. of moisture, while wood seasoned only in the forest contains up to 25 and even more per cent. Some woods may become completely seasoned in a single year, while others, such as *sál*, may take more than 10 years. For trades such as that of the joiner and cabinet-maker, turner and cooper, wood has to be kept for two, three and even more years before it can be used.

*Absorption of moisture.*—The very same circumstances which favour rapidity and completeness of seasoning, also favour the rapidity with which a wood absorbs moisture, whether from the

air or from any liquid in contact with it. Hence the extremely important fact that the longer and more slowly a wood has been seasoned, the more slowly does it absorb moisture. Hence also the fact that oak cask staves cut in December, when seasoning is slowest, allow only half a litre of wine to pass through in one year and become evaporated, whereas similar staves cut from trees felled in January allow a loss of eight litres in the same time.

*Change of volume of wood through loss or gain of moisture.*—As wood seasons it shrinks. Once seasoned, it swells or shrinks with the varying quantity of moisture in its environment. The extent to which this constant change of volume takes place depends on the kind of wood and the accompanying circumstances. Thus—

(a). It is greater, the larger the quantity of moisture contained in the wood is: the wood of young parts, the sapwood, the wood of the roots and of the crown shrink more than heartwood and the older wood of the trunk.

(b). It is slightest in the direction of the fibres, so slight indeed, that for all practical purposes it may be entirely left out of account. It is much greater in the direction of the medullary rays, in which it may reach 5 per cent. of the original dimension of the wood. But it is greatest parallel to the concentric rings, or which comes to the same thing, in a direction tangential to the circumference, in which direction it may reach the high figure of 10 per cent. (*Pinus longifolia*). Hence the best planks to use are those sawn as nearly as possible parallel to a radius.

(c). It is in direct proportion to the warmth and dryness of the environment. Hence the necessity of using only thoroughly seasoned wood for the furniture of dwelling rooms.

(d). For one and the same species it is greatest in close-grained heavy wood. On the other hand, when the species are different, this rule does not always hold good, for there are numerous exceptions. It would be very important to ascertain by careful experiments the amount of shrinkage and expansion of all our principal woods under different conditions of the atmosphere.

(e). Seasoned wood immersed in water swells up at once rapidly, and in from 1 to 1½ months acquires the same or nearly the same volume as it occupied before it was cut. After this there is no, or hardly any, further increase of volume, but the wood continues to absorb more water for the next one to three years, when every pore, even those which contained a large proportion of air in the green wood, will be found gorged with water and unable to take in more.

*Warping.*—If as the volume of a piece of wood changes with loss or absorption of moisture, the shrinkage or expansion is

uniform throughout its mass, the change of volume is not accompanied by any change of form. But if some parts shrink or expand more or less than others, a change of form necessarily occurs, or, in technical language, the wood *warps*. It hence follows that the extent to which a wood is liable to warp is in direct relationship with the extent to which it shrinks or expands with loss or gain of moisture, and we thus find that the softer and lighter woods warp less than those which are harder and heavier. Boards sawn parallel to a radius, since the tissues are thus uniformly distributed, are less disposed to warp than boards sawn parallel to a tangent, which no amount of care will prevent from warping; and similarly, among the latter class of boards, those taken off furthest away from the centre of the log warp most. Boards and scantlings cut out of trees with twisted fibre always warp very badly. Even-grained wood will warp less than wood wanting in uniformity of structure; bamboos and canes are examples of wood possessing conspicuously uniform structure. Warping may be prevented or minimised by steaming the wood (this, however, reduces its strength), or by impregnating it with oil, or, instead of making an article of a single piece of wood, by composing it of several pieces so as to secure every possible direction for the run of the fibres, and thus counteract any tendency to warp in any one direction.

*Cracking and splitting.*—If in unequal contraction the different parts of a piece of a wood cannot move and keep together, and the force with which they are drawn apart from one another is great enough to overcome the cohesion between them, one or more cracks result. Such cracks are most numerous along radii or lines of easiest fission, and least so parallel to the concentric rings of growth or lines of most difficult fission. The size of the cracks increases (*a*), with the rapidity with which the wood dries and shrinks (timber felled during the rains or winter has fewer cracks than timber felled at any other season); (*b*), with the extent of the shrinkage (*c*); with the removal of the bark before seasoning has made any progress; (*d*), with the diameter of the log or breadth and thickness of the scantling; and (*e*), with the want of uniformity in the structure of the wood (the uniform-textured sounding board of musical instruments, looked after properly, scarcely ever cracks). Wood in the round is most of all subject to cracks. This tendency in logs may be diminished by rough-squaring, so as to leave continuous strips of bark at the corners; such treatment, although not preventing the formation of numerous little cracks, checks that of large ones, which often render the wood useless for many purposes. If rough-squaring cannot be resorted to, then in dry climates it

is advisable to leave the bark on for a few months until the wood has undergone a certain degree of seasoning; or the bark should be preserved for a few feet at the ends in order to secure a more uniform drying throughout the length of the log; or the bark should be removed only in spiral strips running round the whole log. Short round pieces, that are ultimately to be cut up, are effectually preserved from cracks by sawing them through lengthwise along a single line as far as the pith; this is the way in which pieces of box for engraving purposes are treated. A hole of sufficient diameter bored through the centre of the log also prevents the formation of cracks. Sawn pieces are protected either by clamping the ends, or by driving iron SS into the ends, or by tarring the ends and pressing on tough brown paper before the tar is dry. Steaming, followed by slow drying, also prevents cracks, or, at the most, allows only a few small ones to form.

#### SECTION VIII.—DURABILITY.

By the durability of a wood we understand the resistance it offers, when brought into use, to the various causes of decay and to the attacks of insects and other animals.

*Decay.*—Decay is the result of the ravages of various fungi, which invade, by means of their fine thread-like mycelia, the entire tissue of the wood, obtaining starch, saccharine matters, nitrogenous substances, and inorganic elements, such as potassium, phosphorus, calcium, &c., from the medullary rays, and other food materials, such as water, air, mineral salts, tannin, coniferin, lignin from the lignified walls of the cells, tracheides and vessels everywhere. The structure of the wall is thus completely destroyed, and the entire mass of the wood becomes brittle and falls easily into powder. As fungi cannot live without nitrogen, wood could be made imperishable were it possible to rid it of all the proteid substances present in the medullary rays. Since fungi require a considerable quantity of moisture, the use of thoroughly seasoned wood in a sufficiently dry environment would effectually prevent decay. So would complete and uninterrupted submergence in water deep enough not to be overcharged with air preserve wood against decay. Indeed submergence for a sufficiently prolonged period renders wood imperishable: during the submergence slow chemical and physical changes go on, by which the starch, sugars, nitrogenous matters, &c., are dissolved out, and replaced by mineral deposits from the water, both the

density and hardness of the wood being thereby increased to a greater extent than in the formation of ebony. On the other hand, situation in a moist, still, warm atmosphere, contact with soil or moist masonry, and alternate submergence and exposure or submergence close to the surface of the water, hasten decay. At most seasons of the year the soil is moist enough for the germination of fungus spores, and, except at a great depth, it contains sufficient air and heat for the purpose. In old posts fixed in the ground, the greatest amount of decay will be found at the level of the ground, and the extent to which decay has progressed in the buried portion will be found to grow less as we examine the wood further down. The more porous a soil is, the more rapidly does the wood decay (witness the fate of railway sleepers laid deep in loose ballast). Wood lasts longest in stiff clay soils, much less in limestone soils (which are not only porous but also act chemically on the wood), and least of all in soils containing much organic matter, especially such as are themselves undergoing decay and decomposition. In experimenting on the relative durability of different woods, the most rigid test to apply is to bury the lower ends of posts or scantlings of one and the same size in holes filled with fresh cow-dung.

Impregnation at any time with antiseptics, such as creosote, sulphate of copper, &c., precludes the vegetation of fungi, provided fungus spores have not already entered the substance of the wood. Fungi may also be kept out indefinitely by covering the wood, where it is to be in contact with a damp surface, with a coat of paint impervious to moisture and therefore also to spores, or by painting the surface over with creosote, tar or any other antiseptic substance. Charring the surface is not always a successful method, for charcoal being a highly permeable substance, may let spores pass in with the water, and in the process of charring deep cracks may form giving ingress to the spores. In any case the charring, to be effective, must be deep, and thus detracts very considerably from the strength of the wood. Woods thoroughly impregnated with resin are practically imperishable.

It is evident that the first step to rendering wood durable is to season it thoroughly; no other precautions, if this one has been omitted, can save the wood from early decay.

All woods are not equally durable, and even in the case of one and the same species some specimens decay more quickly than others. Greater weight is no proof of greater durability in the case of woods of different species, for the lighter wood may contain substances, such as oils, alkaloids, &c., that are poisonous to

fungi ; moreover, the heavier wood may be more subject to cracks through which fungus spores may at once get admittance into their interior. Nevertheless the heavier woods are generally also the more durable. In the case of specimens of one and the same species, this rule is universally true, since the closer the tissues are, the less room is there for the entry of spores. Hence the timber of trees grown in favourable soils and localities, and in the full enjoyment of light and warmth, is more durable than that of trees grown under less favourable conditions. This proves the necessity of thinning timber forests properly, and the superiority of methods of culture which give the future timber trees room for unrestricted development.

The sapwood, being full of moisture and of starch and other reserve materials, decays very quickly, although there are some extremely durable woods, such as teak, thin rafters of which, if properly seasoned, last for over 20 years. In old large trees the wood near the centre has generally already undergone a certain amount of decomposition, and hence is subject to early decay. There are two exceptions to this rule—(1), species in which ebony is formed, and (2), conifers rich in resin, the central zones of which are generally impregnated with this substance.

The season in which a tree is felled has a powerful influence on the durability of its timber. The most durable wood is obtained if the tree is felled when the sapwood and medullary rays contain a minimum amount of starch and nitrogenous substances. The least amount of such substances is found immediately after a gregarious fructification ; in ordinary years, however, soon after the new flush of leaves has come out at the beginning of the season of vegetation.

The following is merely given as an indication of what might be done in classifying our numerous species according to their power of resisting decay. It must not, however, be forgotten that the conditions in which a piece of wood is placed when used affect to a very considerable extent the question of its durability. For instance, the wood of *Ficus religiosa* decays quickly in the open air, but is extremely durable under water.

- (i). Extremely durable.—Teak, *Hardwickia binata*, ebony, *Acacia Catechu*, iron-wood, *Mesua ferrea*, sál.
- (ii). Very durable.—Deodar, *Michelia Champaca*, *M. excelsa*, *Dipterocarpus tuberculatus*, sundri, black-wood, sissu.
- (iii). Durable.—*Albizzia Lebbek* and *procera*, *Schima Wallichii*, *Pterocarpus* spp., oak, *Eugenia Jambolana*, *Terminalia Chebula*.

- (iv). Fairly durable.—*Anogeissus* spp., tun, mango, *Terminalia bellerica*.
- (v). Quick to decay.—*Odina Wodier*, *Adina cordifolia*, semal, *Butea frondosa*, *Boswellia serrata*.
- (vi). Very quick to decay.—*Cochlospermum Gossypium*, *Moringa* spp., *Dalbergia paniculata*, *Sterculia* spp.

*Insects and other animals.*—Except in the special case of wood used in contact with sea-water, the animals we have to fear are insects. For our purpose we may divide timber-destroying insects into three classes, viz., (1), those which can enter only fresh-felled wood as larvæ, (2), those which attack wood already in use, but only as larvæ, and (3), those whose full grown individuals attack the wood and commit all the ravages.

In the first class of insects the mother deposits her eggs on, or in, the bark of fresh-felled wood, and the larvæ, after being hatched, eat their way into and inside the wood. According to the size and number of the larvæ, broad "galleries" are formed, or the wood becomes literally riddled with small holes (*worm-eaten*). To prevent the ravages of such insects, it is sufficient to bark the trees in time, thus getting rid of eggs already laid, and either preventing new ones from being laid, or, owing to the drying up and consequent hardening of the surface of the exposed wood, preventing the weak, freshly hatched larvæ from gnawing their way to the moist and therefore softer tissues inside. The case of the various species of bamboos presents an anomaly in that they have no bark which can be removed; but submergence in water for a few days' or, better still, floating washes off the eggs. Felling bamboos during the dark half of the lunar month also preserves them from the attacks of insects. Prolonged floating or submergence in water also preserves all other kinds of wood by drowning the larvæ. Where the use of such substances is cheap enough and not objectionable, the wood may be impregnated with insect poisons, such as metallic salts, creosote, kerosine oil, &c. Steaming will also of course kill all the eggs and larvæ. The wood of broad-leaved species is more liable to the attacks of insects than conifers, which are partly protected by the aroma of the turpentine. The sapwood, on account of its softer texture and the reserve starch and other food it contains, is very much more visited by insects than the heartwood.

The second class of insects include the genera *Ptinus* and *Anobium* (death watch), which attack wood used in dwellings, especially in dark places in the roof. The larvæ eat their way through the wood in every direction, reducing it to a spongy brittle mass that



crumbles to pieces under the slightest pressure ; while the beetles, when they are not out feeding or mating, live in the galleries where they lay their eggs.

The third and last class of insects comprises almost exclusively the various species of white-ants. A striking instance of the few other families falling under this class is that of a species of Bostrychid beetle which, until the tree is felled or has begun to die, lives in the thick bark of the *Pinus longifolia*, but works its way into the wood within a few minutes of the fall of the tree. The only remedy against this beetle is to bark the trees without delay. As regards white-ants, there are certain woods which are self-protected, either because, like teak and deodar, they contain an oil not relished by the insects, or, like *Salvadora* and nim, they are impregnated with an acrid alkaloid, or because, like *Hardwickia binata* and khair, they are too hard for them. In the case of other woods nothing short of impregnating them, or painting them over with poisonous substances, will protect them against these all-devouring pests.

Wood used for marine purposes is subject to the attacks of certain crustaceans and mollusca, the most terrible of the latter being the barnacle (*Teredo navalis*). Against this last the only sure preservative is to plate the wood with iron or copper. In the case of wood kept in dockyards before use, the best plan is to bury it in mud at the bottom of the tanks, or to reduce the saltness of the sea-water by mixing enough fresh water, as a certain degree of brackishness is essential for the barnacle.

#### SECTION IX.—COMBUSTIBILITY AND HEATING POWER.

By the term "combustibility" we mean the ease or difficulty with which a substance takes fire, and, being once ignited, continues to burn until it is consumed ; and by the heating power of a wood is understood the quantity of heat radiated by a unit of volume or weight of the wood when burning in the ordinary way. The only two elements of wood which burn are its carbon and hydrogen, the former combining with oxygen to form carbonic acid, the latter to form water ; while the incombustible portions remain behind as ash. It is very probable that the combustibility and heating power of the pure wood fibre is the same for all woods, and that the actual differences existing between the various woods are due entirely to differences of structure and the presence of accidental substances, such as oils, resins, &c.

Combustibility is in direct proportion to looseness of texture (guaranteeing free access of oxygen into the interior), to absence

of moisture, and to presence of resins and oils, which enable some woods to burn well even in a very green condition. Decayed wood, owing to its spongy texture, takes fire easily and burns until it is consumed, but, as it has lost a very large proportion of its carbon, its combustion is very slow and unaccompanied with flame.

The conditions which affect the heating power of a given wood are—

(1). *Quantity of contained moisture.*—The most highly air-dried wood contains a large proportion of moisture. When the wood is burnt, a certain portion of the heat produced by the combustion is absorbed in converting the moisture into steam, and not only this, but as the steam rushes out from the inner layers of the wood, it takes up more heat from the burning outside layers. Nördlinger estimates that with 45 per cent. of water present, half the heat of combustion is lost, and with 60 per cent. as much as four-fifths. These figures prove the great importance of drying firewood as thoroughly as possible; all large pieces should be cut into short lengths and split, and the wood should be loosely arranged in long narrow stacks composed of only a single row of pieces, so that both ends may be exposed and air circulate freely between the several pieces.

(2). *Specific weight.*—This is not a safe criterion for woods of different kinds, since other circumstances, such as a greener condition of the heavier wood, resin and oil in the lighter wood, &c., may more than counterbalance the superiority possessed by the heavier wood in respect of its weight alone. Thus the light, but porous and quickly-dried, wood of *Butea frondosa* gives out more heat than several much heavier woods. Nevertheless, for one and the same species superior weight also means superior heating power. Hence the heartwood is better than the sapwood, the wood of the stem than the wood of the branches and roots (resinous conifers of course excepted), the highly lignified wood of trees grown in warm sunny localities and in the open than the wood of trees of cooler climates and aspects and of canopied crops.

(3). *Anatomical structure.*—In the case of the more porous wood the moisture is expelled more quickly, during combustion, from the inner mass of the wood, and hence there is less loss of heat. We have already seen that the more porous wood also burns more quickly. Hence in a confined place, as in a baker's oven, the more porous wood will not only give out its heat more quickly, but also an absolutely larger quantity of heat. For warming rooms a wood of a certain minimum density is required, for if it burnt too quickly most of the heat would disappear through the chimney.

(4). *Smallness of the pieces of wood used.*—The smaller the pieces are, the larger is the surface exposed to a free draught of air, and the greater the quantity of heat evolved. But there must be a limit to the smallness of the pieces, for sawdust burns with little heat, as it does without flame.

(5). *Presence of oils and resin.*—This circumstance requires no explanation.

(6). *Soundness.*—Unsoundness necessarily implies some loss of the original quantity of carbon and hydrogen, the only two combustible elements in the composition of wood. As all trees begin to get more or less unsound at the centre after a certain age, trees intended for the supply of firewood ought not to be kept beyond middle age.

The popular belief that floating diminishes the heating power of wood is totally unfounded. What actually happens is that when floated wood is taken out of the water, the pieces are piled up pell-mell into large heaps, inside which they undergo a certain amount of decomposition. If the wood is dried at once, no loss of heating power will result from the floating.

Numerous attempts have been made to ascertain the relative heating capabilities of the various woods. In some physical methods have been employed, in others chemical methods.

The most common physical method is to ascertain what quantity of water at  $0^{\circ}$  C. is evaporated by one pound of the given wood at a given temperature of the air and under a given pressure. A simpler method is to find out what quantity of ice at  $0^{\circ}$  C. is converted into water of a temperature of  $0^{\circ}$  C. by one pound of the wood. A third method, having another purpose, is to burn separately the same quantity of the several woods in one and the same fireplace, and note the difference between the temperatures of the air of the room at the beginning and end of each burning. The doors and windows of the room should of course remain closed during the experiment.

Chemical methods consist in ascertaining the quantity of carbon and hydrogen present in a given weight of the wood. This is done by burning the wood in a closed retort, either with a direct supply of oxygen gas or with a known weight of some metallic oxide. In the former case we know at once the quantity of oxygen used up, in the other we weigh the balance of the oxide and thus ascertain the quantity of oxide reduced, and therefore of oxygen given up to the burning wood. In either case we are enabled to calculate the quantity of carbon and hydrogen burnt.

The physical methods give results of very little practical value,

while the chemical tests are entirely misleading (the more so, the larger the quantity of hydrogen contained in the wood is). In actual practice the relative value of the different woods depends to a very great extent on the purpose for which the firewood is required, and on how it is to be used. Thus for warming purposes generally we want a wood that does not burn too fast, but gives a steady prolonged heat; but so much here depends on the draught that the value of a given wood will be different according as it is to be burnt in the open (as in a camp fire) or in a fireplace, or in a stove. The difference is still greater for cooking purposes; we have every variety of *chula*, with chimneys and without chimneys, and dishes, some of which require a slow fire, others a quick fire, and so on. The baker and brickmaker require wood that gives out all its heat in as short a time as possible, so that for the short time it lasts, the heat may be intense. For well-made lime-kilns also quick-burning wood is necessary; for the very primitive ones used by most of our Indian lime-burners the wood must not reach full combustion too soon, nor must it burn too quickly, although it must give out an intense heat.

#### SECTION X.—DEFECTS AND UNSOUNDNESS.

The difference between a defect and unsoundness is that the former is purely a discontinuity of tissue, or abnormal development of the fibres, which may interfere with the cutting up of the wood, or at least unfit it for certain purposes, whereas the latter is always some form or stage of decay. Nevertheless, as some defects are often accompanied by decay, it is best to treat both under one and the same head. It is not intended here to treat of the diseases of trees, the discussion of which belongs to the province of botany, but only to refer to them so far as they affect the technical value of wood.

##### ARTICLE 1. DEFECTS.

The principal defects are—(1) shakes, (2) knottiness and exaggerated waviness of the fibre, (3) twisted fibre, (4) rindgalls, (5) covered sections of pruned branches, (6) enclosed dead branches, and (7) interior bark.

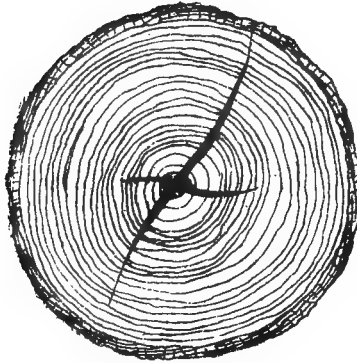
##### 1. *Shakes.*

Shakes are separations of the wood fibres extending along the entire or partial length of the trunk of a tree. According to their position and the direction in which they run on a transverse section they are either (A) Heart-shakes, or (B) Radial-shakes, or (C) Cup-shakes.

A. *Heart-shakes.*—A heart-shake is a crack, which, beginning at the centre of the trunk, extends itself outwards both ways towards

the circumference. Sometimes two or more such cracks occur, to

Fig. 1.



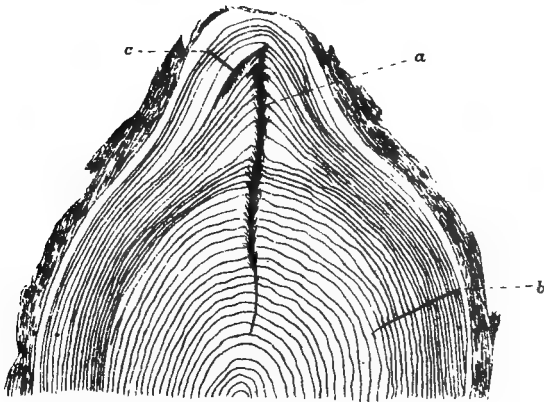
*Heart-Shake.*

which the special name of *compound heart-shake* or *star-shake* may be given as distinguished from the *simple heart-shake*. The origin of the heart-shake is always the drying up and consequent shrinking of the tissue at the centre at the stem. As the surrounding tissues do not contract at the same time, the central mass splits along one or more lines of least resistance, that is to say, along medullary rays or radially. As with advancing age the shrinking continues, the cracks extend outwards as well as grow wider. The drying up and shrinking of the inner tissues may be due to old age, or to weak growth induced by an unfavourable soil or situation, or by forest fires. Hence heart-shakes always begin and are worst at the foot of the affected trees. Sometimes, if owing to one or more of these causes there is a predisposition to this defect, a heart-shake may be produced in a previously apparently sound tree by the shock of the fall when the tree is felled, or even by the mere lurch given by the tree as it begins to fall. Strong winds must obviously aggravate heart-shakes. As heart-shaken logs dry, the cracks continue to extend themselves. To minimise this danger, the logs must not be barked, and must be allowed to season as slowly as possible. A simple device that is nearly always successful in arresting the extension of narrow cracks is to drive a thin wooden wedge into the end of the log just in front of, and across the path of, each such crack. Owing to the position and origin of a heart-shake the wood on the sides of the cracks will generally be found to be more or less decayed, unless the shake

be a very recent one. Logs affected with only a simple shake usually lose nothing of their value as sawyer's timber, but a bad star-shake renders the wood fit only for fuel. Nevertheless very fine compound shakes are no great disadvantage in the case of large beams.

B. *Radial-shakes*.—Radial-shakes, contrary to heart-shakes, always begin at the circumference of the standing tree and extend inwards. They are due to the outer concentric zones of growth

Fig. 2.



*Radial Shake.*

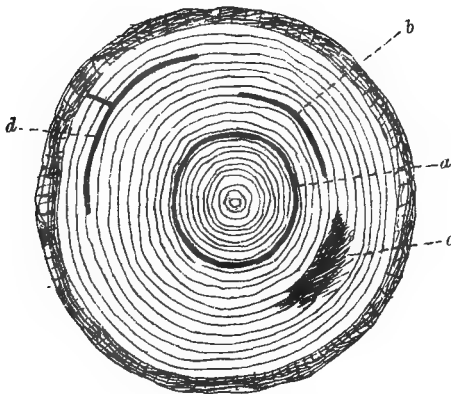
- a. An old one closed. b. A new one still open.  
c. A still more recent one.*

contracting so as to be no longer able to completely encircle the inside solid cylinder of wood. Thus a crack or cracks occur. The contraction may be due to sudden excessive cold, or to a very hot sun after a chilly night, or to hot blasts of wind, or to forest fires; the more sudden the change of temperature the more effective it is, as the difference of temperature between the outer and inner zones is then greater. A radial-shake will always occur on the most exposed side of the trunk. When the difference of temperature which caused the shake has disappeared, the crack closes up, and, in the absence of further accidents for a year or two, may be grown over and completely concealed by the new concentric zones of wood. But, on the other hand, the crack may re-open year after year, in which case a continuous ridge formed by the thicker growth of wood along the lips of the long wound (where of course there is less pressure than elsewhere) will indicate the

course of the shake. In extreme cases the rupture in the formation of the shake may be so violent as to extend to the centre of the trunk. Strong winds may also cause the shake to extend thus. From what precedes we are able to understand why radial-shakes affect trees of large rather than small girth, solitary trees rather than those standing in the midst of a leaf-canopy, portions of a tree where the wood is not of uniform structure (the foot, vicinity of a large knot, &c.) rather than other parts; also why a wet soil and the possession of easily fissile wood and thick medullary plates favour the occurrence of such shakes. The utility of a log affected with radial-shakes will depend on the number and continuity of the shakes, on whether most of them have healed over, and on whether decay has made any progress along the sides of the cracks. In some cases the log may be completely ruined for timber purposes, in others beams and even smaller scantlings may be sawn out of them.

C. *Cup-shakes*.—In a cup-shake the crack follows the line between two adjacent concentric zones of growth, and it may do so

Fig. 3.



*Cup-Shake.*

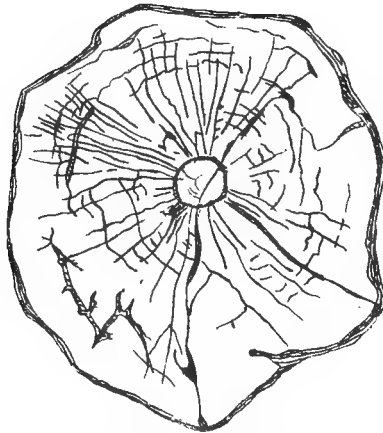
- a. Complete. b. Partial. c. Partial, accompanied with rot. d. Combined with a radial-shake.*

for any distance, from a few inches to the entire length of the circumference. The cause of separation may be (a) excessive expansion by frost of one or more of the outer zones, so that they can no longer fit tight over the enclosed solid cylinder of wood, or (b) violent swaying or bending of the tree, so that the limit up to

which the zones can play upon one another is passed, or (c) heavy concussion when the tree itself is felled or another large tree falls up against it, or (d) shrinking from loss of moisture of the enclosed cylinder of wood. Such being the case, it is evident that trees in which the vessels are mostly grouped together along the inside edge of each concentric ring, are most liable to cup-shakes. Since a great many of our species have not even any distinct rings of growth, cup-shakes are not much to be feared in India. As we might expect, cup-shakes affect more frequently large than small trees (since the former can bend less), and the lower than the upper part of the stem (since it is at the lower part that most bending takes place and the wood is least uniform in structure). The wood in the cracks of cup-shakes is not always decayed, since it is never exposed to the air. The extent to which cup-shakes render timber unfit for use depends on the number and length of the shakes. Badly shaken wood falls to pieces when sawn up. Even a single shake, if it extends all round the circumference, reduces the thickness of the useful timber by the thickness of the trunk outside the shake.

Not unfrequently, in very severe climates, the trunk of a tree is abundantly affected both by radial and cup-shakes, in which case the wood is fit only for burning (*see Fig. 4*).

Fig. 4.



*Exaggerated case of combined radial and cup-shakes, with incipient decomposition. (After Gayer).*



## 2. *Knottiness and exaggerated waviness of fibre.*

A knot is produced by an irregular course of the fibres round an independent centre of growth, such as branches or a dormant bud. Owing to the greater pressure occurring at these places, the fibres are also packed more closely together, and compose a denser and harder tissue than that surrounding the knot. The simplest knot is that formed by a single branch that has attained normal development. In a broad-leaved tree such a knot, as long as there is no decay present, detracts from the value of the wood only when thin planks of good quality are required. It is, however, different with conifers, since the wood of the branches is so entirely dissimilar from that of the stem, that if a branch has not fallen off while it was still only a twig, it runs radially through the tissues of the stem merely like a plug, which ultimately shrinks from loss of moisture until it is easily detachable, even falling of itself out of boards and planks. Such knots are known as *loose knots*. A burr, so much sought after by the turner and cabinet-maker, is a complex knot formed at points where dormant buds show abnormal vigour without being able to develop into branches. In species extremely rich in such buds, as in *Celtis* spp. and maples, the burrs may attain the size of a man's head. Epicorms produce knotty tissue along the entire length of the stem. If they are numerous without ever getting beyond the size of small twigs, an extremely handsome mottling may be thereby produced. The presence of numerous but weakly-formed latent buds gives rise to a wavy course of the fibres, making the wood well adapted for ornamental purposes. This defect, when exaggerated, always diminishes transverse strength very considerably, and usually renders the wood unsuitable for purposes in which heavy strains have to be withstood.

## 3. *Twisted fibre.*

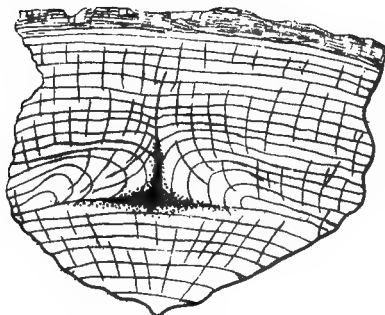
In this defect the course of the grain of the wood follows a spiral round the stem, making with the vertical an angle which may sometimes exceed  $40^{\circ}$ . In most cases this angle increases with the diameter of the stem, the spiral growth being not at all apparent in young saplings. This defect is due to the fibres in each new layer of wood being longer than those in the preceding layer. The cause of this abnormal growth is not yet exactly known. What we know regarding it is that it is hereditary; that certain species (*Boswellia serrata*, *Hardwickia binata*, &c.), are more liable to it than others, that it may be produced by the wind acting

constantly on an unsymmetrical crown, that it is often peculiar to certain localities, every tree therein being affected (*e.g.*, the *Pinus longifolia* forest at Ranikhet just below the road to Almora), and that stunted trees and those growing out in the open are much oftener twisted than tall trees or those standing in the midst of a leaf-canopy. Teak seldom if ever suffers from this defect. Twisted fibre renders wood useless for a great many purposes : it reduces the strength of sawn timber in proportion to the smallness of the scantling, it renders the wood liable to warp and split very badly, and it prevents any kind of effective planing. Wood with twisted fibre has, however, greater transverse strength than straight-grained wood if used as large beams.

#### 4. *Rindgalls*.

These are local wounds that have healed up and been covered over with new layers of wood. The wounds are such as may be

Fig. 5.



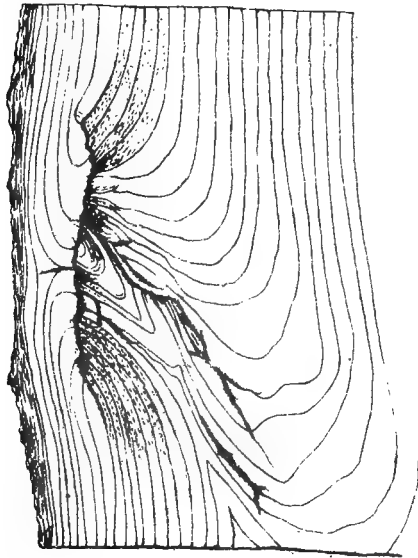
*Rindgall*.

caused by a falling tree, a passing cart, an animal rubbing its horns, &c., or by the bark being killed by fire or hot blasts of wind. There is always a break of continuity in the first few rings formed after the accident, and, however quickly the wound may heal over, there is never any union between the new covering rings of wood and the surface exposed by the wound, and some amount of decay is always present. The portion affected by a rindgall must be cut out of all planks and small sawn stuff, also from cask staves ; and if decay has made any appreciable progress, which is nearly always the case, the entire affected portion must be removed, whatever use the log may be put to.

### 5. *Covered sections of pruned branches.*

However carefully a branch may be pruned off, and even if the surface of section is painted over with some antiseptic substance, there is never any real union between that surface and the new wood that forms over it. If the branch is at all large, saprophytic fungi never fail to enter the section and engender rot (*see Fig. 6.*)

Fig. 6.



*Section showing result of the most careful pruning. (After Boppe).*

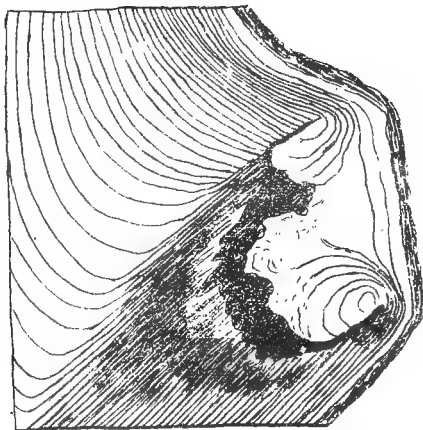
In any case no portion of the section can be left in any kind of small stuff into which the wood may be converted.

### 6. *Occluded broken branch.*

Such branches can of course never form any union with the enclosing rings of wood. The end of such a branch, having for a longer or shorter time after death been exposed to the air and atmospheric moisture, is invariably more or less decayed before occlusion takes place. Hence the tissues of the branch itself and those surrounding it are always in a more or less advanced stage

of decomposition, complete hollows, that are bound to grow larger year after year, often being the result (see Fig. 7).

Fig. 7.



*Occluded dead branch. Notice hollow pocket formed. (After Hartig).*

Whatever use is made of a log containing this defect, the enclosed dead branch and all the surrounding decayed tissues must be cut out.

#### 7. Interior bark.

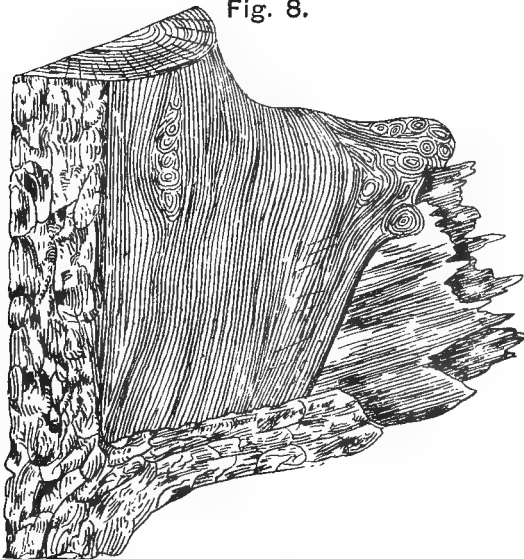
In a few exceptional species having an abnormal mode of growth, such as *Dalbergia paniculata*, *Bauhinia VahlII* and *Millettia auriculata*, either layers of bark are found throughout the thickness of the stem alternating with layers of wood, or the stem is composed of a mass of bark-tissue traversed by strands of wood. This defect is obviously incurable, and the stem is totally unsuitable for use as timber, and even yields a very inferior fuel. In the case of species possessing normal growth, two distinct stems produced on one and the same stool, or the two branches of a fork, may amalgamate and become grafted together laterally for a certain distance. When this happens, the old bark existing previous to the amalgamation remains enclosed in the middle by the newly forming woody layers common to the now amalgamated stems. There is also another instance of interior bark. In trees that form exaggerated flutes, two such flutes may unite laterally and thus shut in the bark between them. Interior bark in these two last cases has no further drawback than to give the unfelled tree a fictitious value in

respect of great thickness, as it never leads to rottenness. There is no way of recognising it until the tree has been felled and cut up, and it must, of course, be removed before the wood can be employed.

#### ARTICLE 2.—UN SOUNDNESS.

In a previous Section, under the head of durability, the decay which overtakes felled and, therefore, dead wood through the attacks of saprophytic fungi was considered. In the present case the unsoundness occurs in the living tree itself, and, besides being due to the decomposition consequent on the oxidation common to all dead organic matter, is occasioned by parasitic as well as by saprophytic fungi. The ravages of the latter are only local, being confined to the dead tissues, while those of the former may extend through the entire tree. The mycelium of such fungi sends out fine filaments in all directions, which dissolve and absorb everything in the shape of food that comes in their way, so that the walls of the tracheides, vessels and cells become attenuated, and from having been closely cemented together and firm and tough and elastic, lose all cohesion and become soft, moist and brittle—in

Fig. 8.

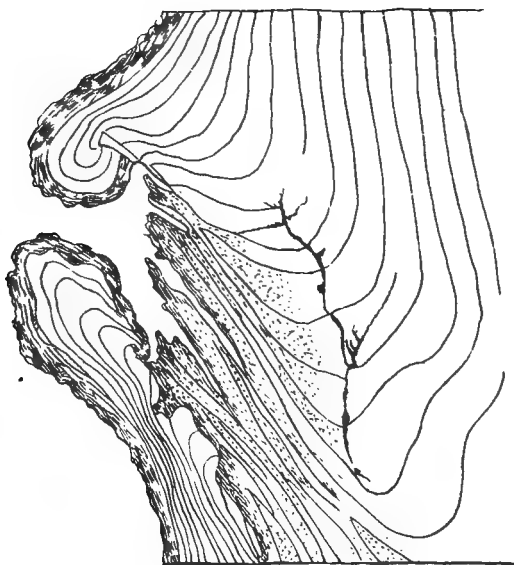


*Broken dead branch.*  
(After Hartig).

other words, the wood becomes "rotten." The rotten elements may fall away in dust and produce a hollow. For our purpose we may consider separately *concealed* rot and *external* rot.

The internal rot caused by parasitic fungi, popularly termed "wet rot," "red rot," "white rot," &c., may find entrance into the tree either by the roots or through a dead branch, or through a wound in the stem. Rot that enters through a dead or broken branch of some size (see Fig. 8) is the most fatal of all to the value of the tree, as it always extends down the entire stem. Both parasitic and saprophytic fungi attack the broken jagged end, which moreover absorbs large quantities of atmospheric moisture. The fermenting action of the fungi converts the wood into a mixture of acid substances, which are carried down into the portions below by the rain soaking into the branch, and which are poisonous to the living parts of the tree. Thus the rot spreads rapidly downwards to the base of the tree. Often a callus grows over the edge of the broken branch, and forms a constantly deepening cup to catch and retain the rain water (see Fig. 9). Rot that enters by way of the roots is the most dangerous

Fig. 9.

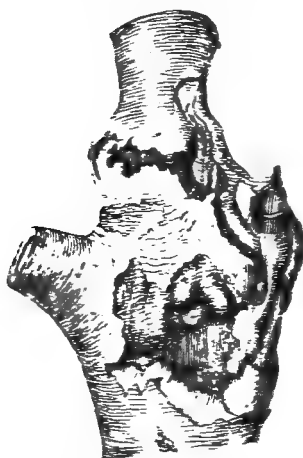


*Hollow formed by callus-formation over edge of a dead branch, and progressive rot. (After Buppe).*

of all so far as the number of affected trees is concerned, since from a single attacked tree as focus it spreads rapidly through the soil from tree to tree in an ever-widening circle, and burrowing animals of all kinds carry away the infection (spores) to long distances in their fur. Sometimes, especially when the rot has spread from a dead or broken bough above, it extends outwards at the base of the tree as far as the bark itself, where it breaks out in the form of a sore (*gangrene*), from which a dark foul liquid, containing the acids above alluded to, oozes out. Internal rot due to saprophytes alone is always local. Its origin is always an occluded wound that has remained open long enough for the fungus to attack the dry, and therefore dead, wood at the surface. After occlusion, owing to the air being shut out, the rot spreads only slowly. Rot of this kind nearly always results in the formation of a concealed hollow or pocket (*see Fig. 7 above*).

External rot usually takes the form of canker. Canker is the

Fig. 10.



*Canker. (After Hartig).*

consequence of imperfect healing of small wounds, the exposed cortex and cambium being attacked by some parasitic or semi-parasitic fungus, as they try to form over the wound. The local disturbances in growth kept up by the mycelium nearly always give rise to malformations and excrescences, from which resinous and other fluids often flow. Hence, by analogy, the name by which these sores are known. There is of course no limit to

the possible spread of the rot, which may, in extreme cases, destroy the entire bole, as shown in *Fig. 11*.

*Fig. 11.*



*Result of injury along the whole of one side of the trunk and consequent rot (After Boppe).*

Having explained in what forms unsoundness may occur, it is now the place here to explain how to detect internal rot, firstly, in the standing and, secondly, in the fallen tree.

In the case of a standing tree the crown and upper part of the bole should be searched for decayed stumps of broken-off branches or holes produced by their complete decay. If such be found there is a certainty that the stem of the tree is unsound for *at least* a portion of its length. To assure one's self further, the trunk should be examined at the base for gangrene, and be sounded with the back of an axe. A hollow sound will be a certain indication of hollowness, a dead sound of a very advanced stage of rot. A clear ringing sound does not necessarily mean that the trunk is quite sound, for if there is a sufficiently thick shell of sound wood outside, the blow of the axe will return a clear ring. If, in addition to giving out a clear ringing sound, the bole is straight, symmetrical and without any prominences or excrescences, the presumption is that the tree is sound. In unfavourable soils and localities the trees have a tendency to become hollow and unsound early, and some species exhibit this tendency more than others. Hence in addition to the indications furnished by the examination of each individual tree, the experience derived from previous fellings should be utilised. If a tree is soon to be felled, it may be



safely put to the really only certain test of cutting into it at the base or boring into it with a large auger. The aspect, colour and odour of the chips removed by the auger will show whether unsoundness is present, and if so, at what distance from the circumference. The auger holes should of course be made along more than a single radius.

The examination of a felled tree is much easier and surer. The log or logs taken out should be examined at both ends. Any portion of the section which is softer and more yielding than the rest should then be carefully looked at to test its colour, structure, hardness, moisture and odour. If this examination of the two ends is satisfactory, and still further proof of soundness is required, a gouge or auger should be used to sound all abnormal prominences or other suspicious-looking spots. Often the odour of the sawdust obtained in logging serves as an excellent indication of soundness or unsoundness.

Logs that have a rotten core along their whole length are quite unsuited for use under trying conditions; but the sound-looking portions may be used for furniture and other articles kept in dry rooms. Where the rot is only local, if the affected portions are completely cut out, the rest of the log may be used for most purposes.

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## CHAPTER II.—THE PRINCIPAL USES OF WOOD.

With the exception of iron, there is scarcely any raw product that serves so many purposes, some of them the most common ones of daily life, as wood. All these various purposes may, however, be grouped together into only two comprehensive categories according as the wood is required for its own sake or only for certain products obtained from its decomposition. We have thus the two great classes of (1) TIMBER and (2) FIREWOOD.

## SECTION I.—TIMBER.

Since, by the preceding definition, timber includes every piece of wood that is manufactured into some article or other without its specific nature being changed, timber may be of any size, and the popular notion that the idea of timber necessarily implies certain considerable dimensions is therefore wrong.

The timber obtained directly from the tree by merely topping it and lopping off the branches is termed *round timber*, or is said to be *in the round* or *in the log*. If the trunk is roughly squared, either with the axe (the most frequent) or with the saw, it is called *balk* or *square timber* or simply a *balk*. A balk that is not quite square is said to be *waney*, the *wanes* being the natural round surfaces of the original trunk, and the *panes* the flat hewn or sawn surfaces. *Rough timber* consists of the trunk or main branches hewn to octagonal section. *Sided timber* is the trunk split down and roughly formed to a polygonal section. In India, where round posts consisting entirely of heartwood is so often used (*e.g.*, *sál tors*), logs of small girth are dressed round. COMPASS TIMBER is squared timber that is curved in one plane.

For such a country as India, with its diverse climates, species, peoples, and modes of life, it is impossible to devise as yet, in English, a classification of the market forms of timber that can be universally adopted. The following is, however, given to show on what lines such a classification ought to be based, and to make ideas more precise in the mind of the student:—

*Round Timber.*

LOGS, pieces at least 6 feet long and having a minimum girth of 3 feet at butt.

ENDS, pieces of the same girth as logs, but shorter than 6 feet.  
 SPARS, pieces at least 12 feet long and between 24 and 36 inches in girth at butt.

POLES, pieces at least 12 feet long, and not more than 24 inches girth at butt.

POSTS, pieces of the same girth as poles, but only from 8 to 12 feet long.

BILLETS, pieces of the same girth as posts, but shorter than 8 feet.

*Sawn timber with at least two parallel faces.*

BEAMS,	}	WHOLE TIMBER,	...	9" × 9" to 18" × 18"
		HALF TIMBER,	...	9" × 4½" ,, 18" × 9"
SCANTLINGS,		...	...	5" × 4" ,, 9" × 9"
PLANKS,	...	...	...	11" to 18" × 3" to 6"
DEALS, (conifers) or BOARDS (broad-leaved species),		...	...	8" ,, 9" × 1" ,, 4"
BATTENS,	...	...	...	4" ,, 7" × ¾" ,, 3"
LATHS,	...	...	...	2" ,, 4" × ½" ,, 1"

ARTICLE 1. TIMBER USED IN SUPERSTRUCTURES.

The superstructures referred to here are those of buildings, of bridges and piers (piles excluded), and other similar constructions.

1. *Superstructures of buildings.*

Speaking in a general manner we have six classes of buildings according as the walls are made (a), entirely of logs (*block-houses* or *log-huts*), or (b), of planks or boards fixed on a framework of scantlings, or (c), of laths or saplings plastered over with mud (*wattle* and *daub* huts), or (d), of mud or sun-dried bricks (*kucha* walls) or (e), of stone or burnt brick joined with mud mortar (*kucha masonry*), or (f), stone or sun-dried bricks joined with lime mortar.

Daub and wattle constructions are from their nature not intended to last for more than a few years. White-ants rapidly destroy all but a few woods, and fungi find every condition favourable for their ravages. In such structures the whole weight of the roof is carried on posts let into the ground or at least into mortar. Hence the posts should be of durable wood and the roof as light-timbered as possible consistent with strength and stability. Hence the roof will consist principally of split or unsplit bamboos, where bamboos are available.

For all other descriptions of buildings, the timber should be durable, especially pieces placed in contact with earth or mortar or used in the roof, which last should at the same time be light and possess great transverse strength. Durability is particularly required in timber used for wall-plates and in terrace roofs, as fungi everywhere, and white-ants in most places in the plains, attack it on the concealed side which is in contact with the masonry. Except in roofs covered with cylindrical tiles or thatch, the timber must be all sawn and squared pieces without any sapwood. Well-seasoned teak poles, floated or washed by the rain during a whole monsoon, last for at least 30 years under well-laid tiles or thatch. The wood used in boarded ceilings and floors and in every portion of a door or window should not be liable to warp, and should expand and contract as little as possible with the varying humidity of the air. The wood of the threshold should be hard and tough, as also that of floors that are not to be matted or carpetted. If beauty and ornament are desiderata, the grain and colour of all the visible pieces of timber should be handsome, especially in doors and windows, and wherever there is any moulding. Wainscoting, by reason of the great abundance of insect life, is out of place in India.

## 2. *Superstructure of bridges and piers and of other similar erections.*

Here, more so than in house building, strength and durability of the highest order are essential, since the structure is not only exposed to the full and continuous influence of the weather, but is also subject to the heavy shocks and vibrations caused by traffic, &c. And in addition the wood must be elastic. Hardness and toughness are also requisite in pieces subject to the direct wear and tear of traffic.

### ARTICLE 2. TIMBER USED ON OR IN THE GROUND.

The principal uses for such timber are for piles, for strengthening roadways and stream banks, for railway sleepers, for timber slides and sledge roads, for palisading and fencing, and for mine props.

#### 1. *Piles.*

For the foundations of bridges and other heavy structures, when a firm bottom cannot be easily reached, long logs are driven into the soft earth in order to support the masonry. As in most cases the logs are placed in the most favourable conditions for the growth of fungi (sufficient warmth, moisture and access of air), only extremely durable wood should generally be used; and as the piles are driven in with heavy blows, the wood should also be as tough and

difficult to split as possible. For this reason, in order to preserve to the full the strength of the log, it should be used quite round. A round section also makes the work of driving the piles easier. If deep water constantly stands over the piles, less durable woods especially such as last well under water, and at the same possess the other requisite qualities, may be used. Trees which grow up with a long straight, clean bole furnish the best piles. Where *sál* grows it is the best wood for the purpose. *Terminalia belerica* has been used under the Mortakka bridge where the Rajputana-Malwa Railway crosses the Narbada.

## 2. For strengthening roadways and stream banks.

In numerous towns in England and America and also in Paris, some of the streets have been paved with short blocks of wood laid, with the fibres standing vertically, on concrete, such roadways deadening the noise of traffic and being less trying for horses than those formed of asphalt or stone pavement, and more durable, less dusty and more easily repaired than a macadamised surface. Woods used for this purpose must be hard and tough, besides being as durable as possible.

On unmetalled roads many portions, from excess of moisture, remain soft during the whole year, or at least for many months after the rains. Such portions are made easy for traffic by laying wood across the roadway. Wood so used is subject to the unchecked action of every influence of decay, and hence unless they can be renewed every year, only durable pieces should be used to form the foundation of the way, only the small branch wood laid on the surface requiring to be put on afresh every year or even oftener according to the volume and constancy of the traffic.

Lastly, stream banks have often to be protected against erosion by forcing the current away by means of spurs formed of wooden crates filled with stones. The crates being always roughly made, are constructed of only round wood, which should, however, be very durable and, if possible, consist exclusively of heartwood. *Sál*, *khair*, *Hardwickia binata*, and other similarly hard and durable woods are the best for the purpose.

## 3. Railway sleepers.

The total mileage of railways in India in February 1890 was, in round numbers, 14,200 miles, requiring, with double lines, sidings, &c., about 32,000,000 sleepers for original construction, and about 3,000,000 annually for maintenance, supposing the way to have been laid only with wood. To meet so enormous a demand has

always, from the first, been a matter of great, and, it may also be said, insuperable difficulty. The wood required for sleepers must be perfectly free from all defects and unsoundness, as durable as possible, and possess great transverse strength. Besides this, it must be hard enough to hold bolts well, and to resist crushing of the fibres, especially when flat-footed rails are used. Such rails are fixed and held in place by dog spikes, which, if the wood is at all soft, are liable to crush the fibres laterally, and thus get loose in their holes through the constant jarring and jolting to which the track is subjected by the moving trains. This danger is most to be feared on curves, on which only very hard woods should be used. Die-square sleepers containing no sapwood at all are of course the best, but about an inch of sapwood on the two edges of the upper face are often not objected to, and half-round sleepers, obtained by sawing a log in two, are often used without any of the sapwood being removed. But in this last case both the diameter and thickness of the sleepers are fixed in excess of the scantlings of a die-square sleeper, and the seats for the rails are adzed flat. If the log to be sawn in two is not straight, or one end is much thicker than the other, this defect must be remedied by adzing or flitching off with a saw the irregular sides or excess width, as the case may be.

The principal woods used for sleepers in India are teak, sál and deodar. *Hardwickia binata* is easily the most durable of all, but it is so extremely hard that special machines are required to bore the holes for the spikes, and even then the holes are bored with much labour.

It was the great demand for sleepers (when the construction of railways was first taken up with vigour soon after the mutiny) and the consequent havoc carried into our forests by the contractors that first directed the attention of Government to the conservation of our forests. The supply was found to be totally insufficient, and the question of substituting metal for wood was at once taken. The Oudh and Rohilkhand Railway laid its rails on cast-iron *pots* connected with an iron tie-rod. The pot sleepers were soon found to be inferior to wooden ones as they produced a rough way, and the constant jarring of the passing trains rendered the metal very crystalline and brittle. Moreover, owing to the way in which the *pots* were connected, if a single one broke, under a moving train, the result was usually the dislocation of a long length of line. Hitherto the most successful metal sleeper used in India is perhaps the trough-shaped one, with which all the new sections of the North-Western Railway have been laid. It is made of a rolled iron

(better mild steel) plate, which is forced under pressure into the form of a shallow trough of the same length and width as a half-round wooden sleeper. At the seat of each rail the metal is cut obliquely away from the rail for a distance of a few inches, and the cut ends are raised so as to form between them a chair between which the foot of the rail fits.

As far as present information goes, the following brief comparison, point by point, between wooden sleepers and metal ones of the trough pattern seems to be justified :—

1. *Appropriate form.*—No practical difference.
2. *Resistance to fracture.*—Wood superior to metal.
3. *Resistance to lateral; longitudinal and vertical displacement.*—Trough sleepers superior, as they can be fixed deep in the ballast, whereas to preserve wooden sleepers, these have to be kept exposed to the air as much as possible.
4. *Durability.*—Life of trough sleeper estimated variously at from 30 to 50 years. Steel rusts more rapidly than iron, which is however liable to be forced out of shape. Sleepers of sound, well-seasoned teak probably last for over 20 years. Merely adzed sleepers cut from undersized logs, so that they contained the pith, have been known to last 14 years, or about the same as the best sal. Deodar requires renewing after about 7 years. *Hardwickia binata* will probably last as long as metal. Creosoted fir and pine from the Baltic rots in 2 or 3 years, sometimes even in the stacks before the sleepers can be placed in the line. Another source of loss before use is due to the formation of large cracks in wood that was previously quite sound. All wooden sleepers begin by being attacked by dry rot on the lower concealed surface, and the progress of the rot may be very advanced even when the visible surfaces are quite sound. White ants sometimes attack wooden sleepers in spite of the constant passing of trains.
5. *Cost of construction of permanent way.*—Cheapness of the one or the other kind of track depends on the local conditions and the state of the iron market.
6. *Maintenance of gauge.*—Metal superior.
7. *Cost of maintenance and renewal of sleepers.*—The advocates of the metal track contend that once it has set, it requires much less labour to maintain than a track with wood; and they also adduce the fact, which is undeniable, that old discarded metal sleepers fetch a much higher price than similar wooden sleepers. But at the International Railway Congress held at Brussels in September 1887, it was decided that sufficient data to come to any conclusion do not yet exist with regard to lines with large and

rapid traffic ; but the greater cheapness of metal tracks carrying medium traffic and slow trains has been proved.

8. *Durability of the rails.*—Wooden track superior. Experience in France tends to show that rails laid on wood last three times as long as those laid on metal.

9. *Effect on the road-bed.*—Wooden sleepers injure it less.

10. *Effect on rolling stock.*—Metal road perhaps less injurious. On the German railways in 1883 the number of tire breakages per 100 miles was 7·25 for a wood-laid way and 5·96 for a metal-laid one.

#### 4. *Palisading and fencing.*

In this place we may leave out of account all fences of a merely temporary character, such as those yearly put round fields and enclosures in villages. The use of wood for palisades and fences is necessarily limited in India by the nature of the climate and the abundance of destructive insects, especially white ants ; moreover, iron wire fencing is very much cheaper and practically imperishable. For standards for wire fences both round and squared pieces are used ; for palisades, battens and planks are required of woods that stand exposure well.

#### 5. *Pit-wood.*

This is required to support the roofs and often the sides of the galleries and shafts. Wood so used remains in contact with constantly moist soil in a constantly moist, warm and still atmosphere, and must, therefore, besides being strong enough to resist all strains, be as durable as possible. The greater portion of the wood used in mines consists of short pieces either round or squared. At Warora *Terminalia tomentosa* and *Diospyros Melanoxyton* are the only woods that have been used up to the present ; but several other kinds are now under trial.

#### ARTICLE 3. TIMBER USED IN CONTACT WITH WATER.

Under this head are comprised piles used in rivers and in the sea, sluice gates and other permanent canal works, water-wheels, wet slides, fascines for protecting river banks, &c. Wood in constant contact with water, especially if it is alternately exposed and covered, or is in shallow water full of air, is placed in the worst possible conditions for its preservation. On this account none but the most durable kinds should be so employed. For fascines for protective works rapid-grown coppice shoots are the best.

#### ARTICLE 4. TIMBER USED IN OR WITH MACHINERY.

The most common Indian instances of wood used in machinery



are the entire apparatus of a Persian wheel, sugarcane and oil mills, pulleys, windlasses, tilt hammers and water-wheels. In cog-wheels used in machinery set up at a distance from a workshop where repairs can be effected, the cogs are best made of some hard, tough wood, since the only part of such wheels that is constantly breaking consists of the teeth, and broken wooden cogs can be at once replaced from a lot kept in stock for the purpose. All parts subject to friction should be made of the hardest and toughest woods obtainable. For the crushers of sugar and oil mills the wood should also be as heavy as possible, like *Hardwickia binata*, khair, iron wood, babul, *Schleichera trijuga*, *Mesua ferrea*. The best woods for axle trees are such as are hard and tough, and have anastomosed fibres, but without knots, such as babul, sissu, &c.

In many cases wood is used in fixing machinery. In order to stand the constant jar and heavy strains while the machinery is working, the wood should be very hard and strong.

#### ARTICLE 5. TIMBER USED IN BOAT AND SHIP BUILDING.

More care has to be exercised in selecting wood for ship and boat building than for almost any other purpose, firstly, on account of the extremely unfavourable conditions in which the wood is used for its durability; secondly, on account of the generally peculiar shape of the different structures; thirdly, on account of the enormous strains sea-going boats have to withstand; and lastly, on account of the serious risks attending a breakdown of any portion of a ship or boat.

The main differences in shape between sea-going boats and those intended for traffic on rivers are—(1), that the former are shorter and narrower in proportion to their depth, (2), that they have a keel, whereas river boats are flat-bottomed, and (3), that the former have curved sides exhibiting every degree of curvature, whereas the lines of the others are comparatively straight.

Timber for boat and ship building, besides being as sound and durable as possible, must be quite free from faults, must be strong and elastic, and must be of the right weight, shape and dimensions.

To give a ship stability the centre of gravity must be precisely at a certain height, and hence the importance of using heavier wood in building the sides than the deck, and the necessity of having the masts light, but at the same time as strong and elastic as possible.

As regards shape the ribs or framework of a ship or sea-going boat must consist of naturally curved pieces (*compass timber, crooks, bends*), the curvature being measured by the proportion between the length of the chord and the height of the arc. The

curvature may be uniform throughout, or most accentuated at about one-third the distance from the thicker end. The necessary curvature is sometimes given by steaming or boiling and then bending, or by hewing the piece to the proper shape; both these procedures, however, weaken the timber very considerably. The framework of well-made river and canal boats is formed of *knees*, which are pieces consisting of the stem and a strong branch making an angle of from  $90^{\circ}$  to  $100^{\circ}$  with the former. The branch portion, which is about half the length of the lower portion, supports the deck. Knees are often used in sea-going boats also for the same purpose. Indian river and canal boats, not being decked, require no knees. The framework of a ship has to bear all the enormous strains caused by the pitching and rolling of the vessel, and must hence consist only of the soundest, strongest, most elastic and most durable woods, weight being of course no disqualification. The sides of the boat and ship are formed of planks fixed transversely across the ribs by means of trenails, which are large rivets of some straight-grained, strong, durable wood. For curved surfaces the planks are steamed or boiled before they are used, in order to render them pliant. The deck requires a light wood with even grain, and one that does not shrink and contract too much with varying quantities of imbibed moisture. Teak is perhaps the best wood existing for decks.

Mast pieces should be of some light but very strong and flexible wood, and should be perfectly straight. Slow-grown pine containing only a small proportion of the soft autumn wood, and having the resin distributed in a uniform manner, is the best. Such pines come from high latitudes, and, the supply being limited, are extremely costly. The usual dimensions of mast pieces are—length from 60 to 80 feet, diameter at thin end from 17 to 22 inches. The main-mast requires pieces nearly 100 feet long and 18-19 inches thick at the top.

In iron-cased ships the plates have to be backed with teak, which is the only wood that does not corrode the metal.

#### ARTICLE 6. TIMBER USED FOR JOINERY AND CABINET-MAKING.

For furniture and house-decoration in any shape wood that works easily, does not warp or split, and holds well at the joints is required. Where beauty is demanded, the colour and grain of the wood should be suitable, and the wood should be capable of taking a high polish. The mottled wood obtained from burrs and tree trunks rendered knotty by numerous dormant buds and small epicorms, is always in great demand; pieces exhibiting such marking

are called *curls*. Dark veins (as in walnut, zebra wood, sissu, some specimens of teak, &c.), a regular wavy fibre (as in many specimens of tun and sissu), or a satiny appearance due to conspicuously bright shining medullary plates (as in satin wood, tun, mahogany, padouk, maple, oak, &c.), also increase enormously the value of wood for the purpose of the cabinet maker. To diminish cost many articles are only veneered with the handsome kinds of wood. Veneers are thin sheets of wood taken off with special saws and by a special process. For curved articles the grain of the wood must be extremely even and coherent, the best kinds being teak, ebony, blackwood, sissu, walnut and deodar.

Other qualities required in cabinet-makers' and joiners' wood depend on the conditions in which any given piece is used. Thus the various parts of a chair and table should be very strong. The wood for portable furniture, such as chairs, should be light, while tall articles, especially those which have a narrow base, require heavy wood below. The sides of drawers should be able to resist friction. For the manufacture of bentwood furniture flexible young wood is necessary.\* And so on. For all articles which stand away from walls and round which the air circulates freely, the question of durability is of entirely secondary importance.

#### ARTICLE 7. WOOD USED IN CARRIAGE AND WAGON MAKING.

Wood used for this purpose should be as light as possible consistent with the requisite strength, hardness and elasticity. The only portion which forms an exception to the rule is the framework of high carriages, which must be heavy in order to keep the centre of gravity low.

The most important part of a carriage or wagon are the wheels. An ordinary wheel consists of a nave (or hub or hob) and of spokes and felloes.

The nave must be able to resist great and violent shearing strains, and the wood must be so dense and hard that these should be unable to enlarge the mortises or holes in which the spokes are fixed and thus render the latter loose. It should contain no sapwood.

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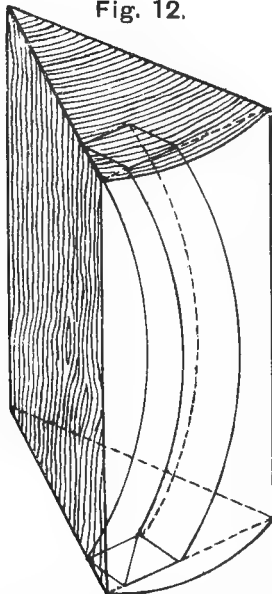
\* The process of manufacture is as follows:—The timber is sawn up into strips from  $1\frac{1}{2}$  to 2 inches square, according to the work for which it is intended, and then turned in a lathe into smooth round rods. These rods are exposed in an air-tight case for fifteen minutes to the action of superheated steam. They are then so soft and pliable as to be easily bent by hand, and are in this condition fitted to iron patterns well secured. When the pieces are dry, they are detached from the pattern and retain permanently the shape given them.

The best woods for naves are babul, sissu, sál, black-wood, teak, various *Albizzias*, and satin-wood.

The wood of spokes should be all heart-wood, very strong and hard, elastic yet rigid enough, not liable to warp or split, perfectly straight-grained, and without knots and any trace of unsoundness. It should be remembered that the whole weight of the carriage or wagon is borne successively by an individual spoke in each wheel, so that a single bad spoke spoils an otherwise perfect wheel. To prevent the tires from becoming loose in hot, dry weather, the length of the spokes should not be liable to vary much with alternations of atmospheric humidity. The most suitable woods for spokes are sissu, sundri, teak, and babul.

The felloes should be made of some wood that is able to resist crushing, is hard, elastic and strong, does not warp or split and is not liable to excessive expansion or contraction with varying quantities of imbibed water. Durability is also an essential quality, and hence no sapwood should be allowed to remain. To preserve all the strength and elasticity of the wood, the fibres should be cut across as little as possible, and hence the advisability of using naturally curved timber. When such pieces are not obtainable, then the felloes should be hewn out of split sections, as represented in *Fig. 12*, so that the concentric rings may all lie

Fig. 12.



Mode of cutting out felloes.

as much as possible in the same plane as the wheel. The best woods for felloes are teak, babul, sissu, sál, nim and oaks. In many parts of India, where the ground is flat and the soil sandy, no tires are put on the wheels, and in that case hard, tough woods, like babul and sissu, answer best. In some parts of Europe "bent rims" are used as felloes for the wheels of light carriages, and occasionally the entire circumference of a wheel is formed of a single bent piece.

In teak-growing countries solid wheels for wagons are made, consisting of three pieces joined laterally, and held together by the tire and by a pair of iron disks, one on either face, strongly rivetted together. The axle passes through the middle of the centre piece. Such wheels are extremely strong and durable.

In almost every part of India the axles of numerous carts are entirely of wood. To resist the enormous transverse strains due to the weight of the body and load and the heavy jolts on a rough country road, and constant severe friction, the wood should be very strong, hard, tough and elastic. The best axles are furnished by *Anogeissus latifolia*, sál, sundri, babul and *Olea ferruginea*. When the ends, on which the wheels revolve, are of iron, almost any strong hard wood will answer for the intermediate portion of the axle.

The poles and shafts of carts and wagons drawn by oxen should be very strong and elastic, the best woods to use are *Ougeinia dalbergioides*, *Diospyros Melanoxylon* and sál. The poles and shafts of carriages have to be light, and therefore thin and extremely strong and elastic. The best Indian wood for the purpose is sundri; but *Diospyros Melanoxylon*, *Anogeissus latifolia*, various species of *Grewia*, and well-selected and seasoned bamboo are also found to be excellent and are used on a large scale.

The framing of carts and wagons must be made of very strong wood that holds well at all joints without splitting or breaking off. The wood in the frame-work of carriages must also be strong, and for some kinds of carriages, such as phaetons, it should also be naturally curved. The rest of the body of every kind of vehicle may be made of any light wood that is strong enough for the part where it is used. For carriages every bit of it should be thoroughly seasoned and not liable to split or warp, or to shrink or expand in an excessive degree. Teak answers excellently all requirements. Those portions which are not painted must possess a handsome grain and colour.

What has been said with regard to carts and wagons apply, with obvious modifications, to wheel-barrows, hand carts, &c.

As regards railway carriages and wagons, the wheels, axles and

framing of the floor are of steel or iron. The sides and roofs are usually of wood of the very best quality—usually teak.

Gun carriages are subject to much more severe strains than any other class of vehicles. Hence great care must be exercised in choosing wood for them. Those portions on which the guns rest must also be very hard and tough, so as to resist friction well.

Sledges must be as light as possible. Hence only the strongest woods should be used. The runners are subject to enormous friction; they are therefore armed with removable soles, about  $\frac{3}{4}$  inch thick, of some extremely hard wood. In the Western Himalayas *Quercus dilatata* furnishes the best soles.

#### ARTICLE 8. COOPERS' WOOD.

The cooper makes casks, barrels, tubs, pails and buckets for holding both liquids and dry goods. For holding liquids the wood should not be so porous as to allow any appreciable quantity of the contents to filter through. Moreover, it should not communicate any unpleasant or undesirable taste or odour to the contained liquid, nor impart any objectionable colour. Certain dry goods must also be similarly protected. Portable casks that are to contain liquids must be made of very strong wood, because of their great weight when full, and in order to withstand the constant violent shocks to which every portion is exposed whenever there is a jolt or shake; and it must be remembered that the slightest crack or flaw will cause the liquid to run out.

The large quantities of rum and other spirits distilled in India and the rapid growth of the brewing industry in every part of the country will soon require a large supply of staves for casks and barrels. The staves should always be split, but English brewers seem to be indifferent to whether those they use are sawn or split. For a hogshead are required

20 staves 3' 3"  $\times$  6" or 5"  $\times$  1 $\frac{1}{4}$ " and

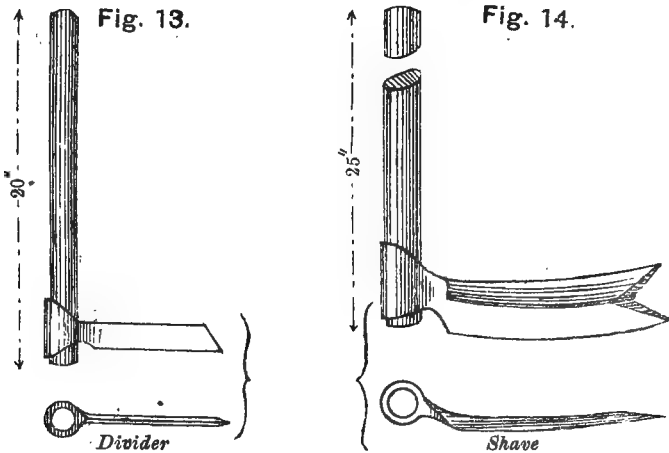
10 head-pieces 2'  $\times$  8" or 6"  $\times$  1 $\frac{1}{2}$ ".

The head-pieces are the staves that go to form the top and bottom of the cask. Before they can be put together the staves have to be properly shaped and shaven, those forming the sides of the cask being kept thickest and broadest in the middle. When thus prepared, these latter are 3' 1"  $\times$  5" (in the middle)  $\times$  1 $\frac{3}{8}$ ". The head-pieces are reduced to a thickness of 1 $\frac{1}{4}$  inches.

Owing to want of enterprise the doubtless numerous kinds of Indian woods suited for cooperage work have hitherto remained unutilized. We cannot therefore do better than adapt from Boppe's *Technologie Forestière* his excellent description of the manner in which cask staves are made in France.

The staves are made principally in the forest, since wood is split most easily when it is fresh felled; also because it is not every piece of timber that is adapted for the purpose, and in the forest itself the workmen can best choose only what is really suitable, and can often utilize the tops and butt ends which the sawyer rejects.

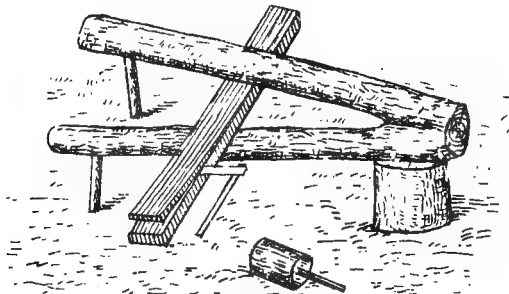
Three tools are used—an axe with a broad flat head like the back of a wedge, the divider and the shave. The last two tools are clearly represented in *Figs. 13 and 14* below :



*Stave-maker's tools. (After Boppe).*

The stave maker's bench (*Fig. 15*) consists of the fork of a tree

**Fig. 15.**



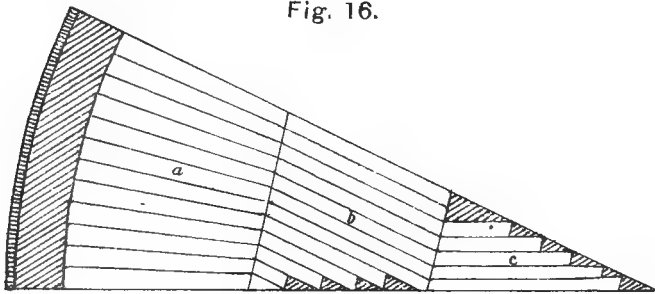
*Stave-maker's bench with divider and mallet. (After Boppe).*

fixed on three stakes firmly driven into the ground.

The mode of working is briefly as follows :—Billets or rounds of the required length being sawn off the logs, they are split with the axe into quarters, and each quarter, if large enough, into sectors (*Fig. 16*).

The divider with a wooden mallet now comes into requisition. The sapwood and pith portion of each sector is removed, and the sector is split tangentially into pieces of the width of the staves to be made. These pieces are fixed on the bench as represented in *Fig. 15* and finally split up into staves. The divider being driven into the wood, the slit is extended by pressing on the handle and pushing the blade in further as the wood splits more and more. To facilitate this process it may be necessary to use the mallet now and then. The staves may be taken off by splitting the sections radially or along the lines of the medullary rays as at (*a*) in *Fig. 16* or along parallel lines as at (*b*) and (*c*). The faces of the staves

*Fig. 16.*



*Method of splitting wood for cask staves.  
(After Boppe).*

obtained by the former method are made parallel with the shave ; this method is hence a more wasteful one than the other.

On the continent of Europe manual labour is sometimes replaced by special machinery, which turns out staves of much truer shape and size. But the action of such machines is partly a splitting, partly a cutting one.

In England the staves are cut with circular saws, and, after being shaved on one, the future inner, side, are steamed and pressed to the required curvature. This practice obtains also at Bordeaux, being not only much easier than splitting, but affording the advantage of utilizing seasoned wood.

Wooden hoops are now seldom used. They are furnished by poles and saplings, young stool-shoots being the best. If poles are utilized, they are first trimmed straight and clean and then split. The hoops are made by forming them on blocks of the re-



quired girths while the wood is still green. If it has been allowed to dry, it must be steamed or soaked in water. Hoops for pails are always of rectangular section (about 2"  $\times$  1½"), and are split from pieces of large diameter.

From what precedes it is evident that the wood used for cooperage purposes must have straight and parallel fibres, and be quite free from knots and other flaws and from every kind of unsoundness.

#### ARTICLE 9. SPLIT WOOD FOR OTHER PURPOSES.

Split wood is used for shingles for roofs and walls, for rudders and oars, for trenails and pegs, for drums and sieve-frames, for veneers and thin boards, for matches and match-boxes, for musical instruments, and for lead pencils.

##### 1. *Shingles.*

Wooden shingles can be used only in cold dry climates where snow lies in winter. Actually their employment is confined to the Western Himalayas, where the wood principally used is deodar, which is not only very durable, but is also light and easily split. *Pinus longifolia* and *excelsa* are also largely used, and to a certain extent also the spruce and the silver fir.

##### 2. *Rudders and oars.*

The woods used must be highly elastic, very strong and durable, and not given to warping and splitting. Where teak is obtainable, that species alone is used. On rivers in Northern India the paddles are made of sál and sissu principally.

##### 3. *Trenails and pegs.*

Trenails are made of teak, since they must, if possible, be more durable even than the ribs and sides of the ship. They are from 16 to 28 inches long and 2 to 2½ inches thick.

Shoe and boot-makers and furniture-makers consume a very large quantity of wooden pegs. Any wood will do for pegs, which is tough and strong; it need not be hard, and yet it must not be so soft as to get flattened out when being driven in. An easy way to test wooden pegs is to bite the end between the teeth; unsuitable wood is easily bitten out of shape. Information regarding the species used is required. Bamboo pegs are very largely used by carpenters.

In this place may also be mentioned skewers for trussing up meat. Bamboo of any kind seems to be the most suitable wood for the purpose.

#### 4. *Drums, sieve-frames and band-boxes.*

The Indian double-headed drum is made out of a whole piece of wood hollowed out ; but the single-headed drum is, like the frames of sieves, made of a single band of split wood. One of the best woods for drums is the *Pterocarpus Marsupium*, which is remarkably sonorous ; but any straight, even, and sufficiently close-grained wood will be suitable. For sieve-frames the choice is less restricted, and a soft wood, provided it is tough enough, will answer. The bottoms of coarse sieves are often made of woven strips of bamboo.

Band-boxes can be made only of woods that split well and can be easily bent into shape. The wood may be split into sheets as thin as the wood in match-boxes, or into boards nearly half an inch thick. The best woods for the purpose are conifers, on account of their long fibre and simple uniform structure.

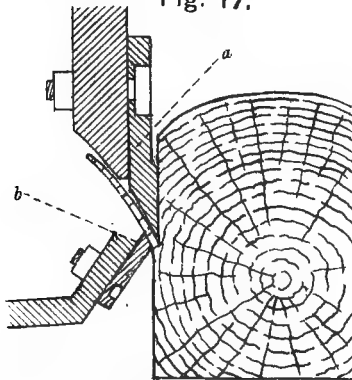
Under this head we may include the wood used in the sheaths of swords, knives and daggers. Simal is largely used for the purpose when coniferous wood is not obtainable.

The boards and thin sheets required for the purposes treated under this head are most easily split with special machines, a most effective pattern of which will be found briefly described under the next head.

#### 5. *Veneers and thin sheets of wood for various purposes.*

For veneers only ornamental woods that are also close-grained, tough and elastic can be used. They are often sawn with thin band saws, but they are best obtained by a process analogous to splitting. The Plessis machine is one of the most convenient and effective for this purpose (see Fig. 17). It consists essentially of

Fig. 17.



*Plessis machine for cutting out thin sheets of wood.*  
(After Boppe).

(a). Planing iron. (b). Heel to prevent sheet of wood from breaking or splitting off irregularly.

a heavy planing iron (*a*) working vertically on two guides, which can be shifted about horizontally, so that the edge of the blade may be moved along any given curve. The heel (*b*) moves *pari passu* with the plane, and, as it presses up against the sheet of wood being cut out, prevents the latter from breaking or tearing. The wood to be treated is first cut up into billets of the required length. These billets, before being placed on the machine, are roughly squared and thoroughly softened by steaming. As soon as a billet has been cut up, the sheets are all put into drying presses heated with steam. They remain in these presses for a variable time, the average being about one minute for every one-twentieth inch of thickness.

#### 6. *Wood for matches and match-boxes.*

For matches we require wood that is easily split and burns steadily with a flame. It should, therefore, be soft. Conifers answer best. Match-sticks, or splints as they are called, are made from solid blocks cut to twice the length of a match, and having a square section of about 3 inches side. The blocks are first steamed and then placed in a special machine which knocks off several splints at a blow. The splints are dipped at both ends into the ignitable composition and cut across in the middle when dry.

The boxes are made of any soft wood that splits easily. All knotty portions are removed, and the wood is divided into small parallelepipeds of square section, which are then split by a special machine. Before the thin boards are pasted into the form of the box or cover, they are smoothed inside a revolving hollow roller.

#### 7. *Wood used for certain musical instruments.*

These instruments comprise those of the violin class, guitars, mandolines, zithers, and sitars. For them the fibres of the wood should be cut through as little as possible in order to preserve their sonority. The wood should be completely free from every kind of flaw, and the grain should be straight, parallel and uniform, so as to secure even vibrations throughout and to prevent warping. The wood should also be thoroughly seasoned, and as little as possible liable to change of volume with alternations of moisture and drought. The bellies or sounding boards of the instruments are best made of conifer wood, while the sides may be made of some harder broad-leaved species. It is superfluous to say that sitars are the only instruments of this class made in this country.

7. *Wood for lead-pencils.*

The manufacture of lead-pencils is an entirely new industry in India, there being only a single factory at Poona. Wood for lead pencils must be even-grained, without knots, and, while tough, nevertheless easy to cut with a knife.

## ARTICLE 10. WOOD FOR VARIOUS ARTICLES WROUGHT WITH ADZE AND CHISEL.

Such articles are the backs of brushes, saddle-trees, shoe-makers' lasts, bowls and platters, spoons, moulds, rakes, clogs, toys, idols, gun-stocks, &c. For all of them only wood that does not crack or split or warp must be used. For the majority of them the wood should also be hard and tough. Wood used in any kind of saddlery must, in addition, be elastic.

## ARTICLE 11. WOOD FOR TURNING AND MOULDING.

For both these purposes even-grained wood that takes a good polish is sought after. In most cases handsome colouring and marking are desiderata. Ebony is perhaps the best wood we possess, but we have a host of other extremely valuable woods—satin wood, blackwood, sissu, tun, teak, padouk, zebra wood (*Pistachia*), *Pterocarpus* spp., box, sandal wood, &c.

## ARTICLE 12. WOOD FOR ENGRAVING AND CARVING.

For wood engraving we require wood that possesses a perfectly uniform texture, is close-grained (so as not to absorb inks and colours too freely), and is so hard and tough that the sharpest edges that can be cut withstands the heavy pressure to which it is subjected in the press. Box is pre-eminently the engraver's wood, but for rough wood-cuts any sufficiently even grained and compact wood will answer.

For carving and ornamental relief work similar wood is required, although the texture need not be so uniform and close or the grain so hard and tough. For open carving the wood should possess considerable transverse strength. Teak, on account of its durability and colouring, is greatly prized for all kinds of carved work. Sandal wood and ebony are used for fine ornamentation. Other good woods are sissu, blackwood, walnut, satin wood, *Adina cordifolia*, *Stephegyne parvifolia*, *Holarrhena antidysenterica*, *Wrightia* spp., maples, and a great many other species.

## ARTICLE 13. WOOD FOR PACKING CASES.

The characters common to all woods used for packing cases are that they should be easily worked, light, yet strong enough for the

purpose to be served, soft enough to allow nails to be driven in without splitting, and not liable to stain or taint or otherwise injure the contents. Deodar, although an excellent wood in every other respect, is generally too oily and strong-scented for any purpose.

One of the chief Indian industries requiring packing cases is tea manufacture. There are several sizes of cases to contain definite weights of tea, but in all the boards are only  $\frac{1}{2}$ -inch thick.

According to Mr. Gamble the common tea-box woods in the neighbourhood of Darjeeling are tun, *Duabanga sonneratioides*, simal, *Canarium bengalense*, *Anthocephalus Cadamba*, *Acrocarpus fraxinifolius*, *Tetrameles nudiflora*, *Acer Campbellii* or *lævigatum*, *Engelhardtia spicata*, *Echinocarpus dasycarpus*, *Nyssa sessiliflora*, *Machilus edulis*, and *Beilschmiedia Roxburghiana*.

In the Dehra Dún mango is the only wood in which the planters pack their tea, although there can be no doubt that numerous other woods will be found to be equally suitable. In Chhota Nagpur even such an inferior wood as *Boswellia serrata* is employed.

Information under this head is required from the tea districts of Assam and Cachar, Kumaon and Kangra. Besides the qualities essential to all kinds of wood used for packing cases, wood for tea boxes must also possess the necessary one of not corroding the lead lining. Green wood of most kinds has this injurious effect, notably *Erythrina* and the wild mango, and, according to Dehra Dún tea planters, also *Pinus longifolia*. Teak is used in some places, but it is far too valuable a wood to be wasted on tea boxes.

Opium manufacture also requires a very large quantity of wood, *Boswellia serrata* being chiefly employed. The wood of this species is not at all strong, but as it seasons very slowly, it is probably useful in keeping the opium moist.

#### ARTICLE 14. WOOD FOR AGRICULTURAL AND GARDEN PURPOSES.

Under this head we have ploughs, harrows, hoes, clod-crushers, rollers, poles and laths for training climbing plants, thorn fences, rakes, hay forks, tool handles, &c.

The plough is made of any hard and strong wood that consists of the stem and a large branch making the required angle with it. In teak-producing districts that species is almost the only wood used on account of its great durability, and the ease with which it is worked. In the Himalayas various species of oak are utilized. Sál, sissu and babul also make excellent ploughs. The shaft is made of any strong, elastic wood, the best being *Ougeinia dalbergioides*, *Diospyros Melanoxyton*, sál and species of *Anogeissus*. The yoke is made of the same wood as in the case of carts.

Bullock hoes, being confined to the teak-producing provinces, are made of teak, the shaft and yoke being of the same woods as in the plough.

In harrows and rakes the teeth must be made of some strong tough wood that wears well under constant heavy friction. Sissu and babul are the species mostly used.

For clod-crushers and rollers any hard and heavy wood will answer, the heavier the better, such as *Hardwickia binata*, sál, *Mesua ferrea*, babul, &c.

Small wood is so cheap and easily obtainable in most parts of India, that for poles and other supports for climbing plants any wood that will last through one season is considered good enough, except in the case of well-kept gardens and orchards, when only the most durable woods, such as teak, sál, &c., are used.

Forks for hay-making and for lifting up branches (especially thorny ones) for hedging purposes consist of a single stem terminated by two equal branches starting from the same point. The wood should be light and at the same time very strong and tough. The same qualities are required in wood for the handles of picks, hoes, spades, shovels, axes, &c. Solid bamboos are excellent for axes, hoes and picks, the thicker end being cut just below a knot that cannot slip through the eye. Species of *Zizyphus* and *Grewia* also make very good tool handles. In the Western Himalayas axe handles made of *Cotoneaster bacillaris* often last three years.

#### ARTICLE 15. TIMBER FOR VARIOUS MISCELLANEOUS PURPOSES.

There is a very large demand for lance staves in every military country of the world. Straight, solid, gently tapering bamboos are unrivalled for this purpose, but they are extremely difficult to procure at present, and the German army is now adopting hollow iron instead of wooden staves.

Wooden combs are in universal use among natives, the woods used being box, ebony, *Stephegyne parvifolia*, *Adina cordifolia*, sissu, bamboos, several *Gardenias*, and several other species with straight and uniform grain.

Wooden hat pegs are to be found in almost every house furnished according to European ideas. Any wood capable of being turned and of taking a good polish is suitable for the purpose.

Handles for chisels absorb a fairly large quantity of small timber. *Terminalia tomentosa*, khair, sissu and teak are very generally used, the first two being the best.

Anvil blocks and blocks on which butchers cut their meat require

a hard tenacious wood, sál and babul being excellent for the purpose.

The manufacture of walking-sticks consumes a considerable quantity of branch wood and saplings. Amongst monocotyledons we have canes, bamboos, and palms; amongst dicotyledons we have oaks, cotoneaster, ebony, *Mimusops indica*, *Alangium Lamarckii*, *Prinsepia utilis*, &c., &c.

#### ARTICLE 16. WOOD FOR BASKET AND MAT-MAKING.

Bamboos and canes are *par excellence* the materials for making baskets and mats. The bamboos should be cut for the purpose before they are a year old, as they afterwards become too highly lignified to split well or to bend and take new shapes easily. Dicotyledons largely employed for basket-making are willows, *Vitex Negundo*, *Nyctanthes Arbor-tristis*, *Homonoya riparia* and numerous other shrubs forming a profusion of long, twiggy, highly flexible shoots. In every case the wood should be used in a green condition; the fresher cut, the better. Wood for basket-making, although flexible while green, should become fairly rigid when dry, in order that the articles made from it may keep their shape. For this reason climbers are seldom suitable for the purpose. In the case of dicotyledonous species stool and pollard shoots furnish the best material.

#### ARTICLE 17. WOOD USED FOR THE MANUFACTURE OF PACKING MATERIAL.

Thin shavings of wood are now coming largely into use for the packing of brittle articles. This wood wool, as it is called, is very rapidly prepared by special machinery, which will work up pieces as small as  $\frac{1}{2}$ -inch in thickness and 6 inches long. The softest woods, possessing long, straight, and parallel fibres, will furnish the best material.

#### ARTICLE 18. TEXTILE WOOD-FIBRE.

Wood wool, as described in the preceding Article, is digested in a solution of sulphuric acid in hermetically sealed, slowly rotating boilers, the encrusting matters being thus separated from the cellulose, which becomes white and lustrous like silk. These thin strips of fibre are then dried in special ovens, in which they acquire great toughness and elasticity. They are now moistened and passed between grooved rollers, which, in flattening them out,

displace the fibres to such an extent that a little twisting suffices to separate these last from one another. In this condition the fibres may be spun and woven like cotton or flax.

#### ARTICLE 19. WOOD PULP.

Paper consists of cellulose with some sizing substance added in order to prevent ink from running. Hence, if we remove from wood everything but its cellulose, we get paper-making material, or, as it is called, paper stock. Paper made entirely of wood stock is, with the sole exception of that manufactured from young half-lignified bamboos, rather brittle and coarse-grained; but, on the other hand, it takes a cleaner impression and wears away the type less than printing paper made from linen or cotton rags. Moreover, wood pulp is very much cheaper than stock prepared from rags. Mr. Routledge, the great paper manufacturer, made samples of paper from bamboo stock, which were equal to the finest qualities of linen and esparto paper.

Wood pulp is not only used by the paper manufacturer, but serves for a variety of other purposes. By penetrating it with special glutinous substances and subjecting it to high pressures, it can be made as hard and as durable as one pleases, and be moulded to any shape. Picture-frames, toys, ornaments, &c., are thus made; also slabs, which may be substituted for boards and planks, and are practically unbreakable, and cannot warp or split even in the most trying surroundings. In America solid railway-wagon wheels are made of a skeleton of steel with specially prepared wood pulp forced in between under great pressure. Such wheels last very much longer than purely iron or steel wheels, and, being of much more elastic material, produce very little jar, and minimise wear and tear of the rolling stock and permanent way. The loose fibre is used for stuffing cushions, as packing material and for filtering water.

The pulp may be made either (I.), by physical means, by rending asunder the fibres between grind-stones, or (II.), by separating the fibres chemically by maceration.

I. THE PHYSICAL PROCESS.—The wood should be fresh-cut. It is first barked, divided into short sections, about a foot long, and split up, all knots and decayed portions being removed. The small pieces are then broken and ground up in the mill, through which a constant stream of water is kept flowing. The water carries off the broken fibre and dissolves away all clogging substances. The coarser portions carried down by the water are separated by



a special contrivance, and ground down again to the necessary fineness. When the reduction is complete, the superfluous water is removed, and the pulp is sorted out into different qualities according to its fineness. In Germany alone over 6,000,000 cubic feet of wood is made into pulp by this method. The pulp thus obtained is used principally as paper stock.

II. THE CHEMICAL PROCESS.—The wood is divided into billets and barked. The billets are then sliced obliquely by a special cutting machine into pieces about  $\frac{1}{2}$ -inch thick. These pieces are passed between fluted rollers, which break them up into chips about  $\frac{1}{2}$ -inch long and from  $\frac{1}{6}$  to  $\frac{1}{4}$ -inch thick. The chips are next put into pierced iron barrels placed inside a large boiler. The boiler is then hermetically closed and completely filled with a strong lye of caustic soda, and fires are lighted below. After from three to four hours, during which the pressure of the steam inside reaches a maximum of about 10 atmospheres, the process of digestion is complete, the fires are put out, and the boiler is emptied and opened. The contents of the barrels, which is now pure cellulose (the maceration having dissolved away all the coating and cementing substances), are thoroughly washed with plenty of water, refined and bleached, and passed between several sets of rollers, from the last of which the entire mass issues forth in appearance resembling a large sheet of felt. The sheets, while still moist, are sprinkled over with sand and rolled up and formed into bales.

From the lye after it leaves the boiler, and from the first washings, from 75 to 80 per cent. of the soda is recovered and can be used over again. The substance obtained by this process is the pure cellulose of the wood in an unbroken condition, and is, therefore, not only adapted for paper stock, but also for the manufacture of pressed articles, for stuffing cushions, for packing, for filtering, &c. The yield of cellulose by this process is roughly 25 per cent. of the air-dried weight of the wood.

MR. ROUTLEDGE'S METHOD OF PREPARING BAMBOO FIBRE FOR PAPER STOCK.—According to this gentleman the young bamboo culms, while they are still semi-herbaceous, should be passed between two rollers resembling the rollers of an ordinary iron sugarcane mill. This crushing presses out all the sap and glutinous substances, and reduces the culms to the condition of long flexible ribbons, which, after being dried, can be made up into easily exportable bales. The cleaning and bleaching processes can be effected at the regular paper mills as in the case of rags and raw fibres.

WOOD SUITABLE FOR PAPER STOCK.—Dark-coloured woods are

always unsuitable, since their bleaching would be unnecessarily laborious and costly. Heartwood is also inappropriate, firstly, on account of the dark colour, and secondly, on account of the encrusting matters that cause the sapwood to become heartwood. It is evident that the wood should also not be too hard. Poplars, willows, the firs, most of the pines, species of *Sterculia*, *Boswellia*, and other soft and rapidly growing species will doubtless prove excellent for the purpose. The best wood is furnished by stems not exceeding 1 foot in diameter.

## SECTION II.—FIREWOOD.

In spite of the innumerable different requirements of the population in respect of timber, the demand for firewood is many times larger, and will not only remain so, but will even increase in greater proportion with advancing civilisation and wealth and higher prevailing standards of comfort. Considering fuel for cooking purposes alone, the annual consumption, at the very moderate daily rate of 1 lb. per head per day, must already exceed 300 millions of solid cubic feet. Insufficiency and badness of communications keep down the demand as well as the supply brought into the market, and millions of cubic feet rot or stand unprofitably in the forest owing to impossibility or prohibitive cost of export.

Firewood may be used for two sets of purposes, *viz.*, (1) directly for the heat and light it gives out in burning, and (2) indirectly for certain products which form when it is burnt.

### (1). *Wood burnt for heating and lighting purposes.*

Wood may be burnt until it is consumed, or it may be burnt only to a limited extent and converted into charcoal for future use.\* Wood charcoal gives out the highest calorific effect of wood, and is hence alone used for smithy and foundry work and for other purposes which require not only a steady and prolonged, but also a very intense, heat. For glass-making and ore-smelting also charcoal should exclusively be used, but owing to the primitive condition of the arts in India, the hardest and heaviest woods are sometimes employed. For the production of steam (as for driving machinery, soap-making, laundry work, &c.), charcoal is the best, but with a strong draught the harder woods yield completely satisfactory results (the softer woods are not used at all, because they burn too

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\* The manufacture of charcoal will be described in detail in Part III.

quickly, and hence do not maintain a sufficiently steady heat). For the kitchen also charcoal holds the first place, both on account of the even heat it gives out and for its burning without smoke. Hence the exclusive use of charcoal for roasting, baking, and grilling; but when wood can be used, the choice between the soft and light and the hard and heavy kinds depends on the nature of the food to be cooked according as it requires a quick or a slow fire. The baker, the potter, the tile and brick-maker, the lime-burner, the stoneware manufacturer, &c., require a fuel that burns readily and gives up all its heat quickly, and hence prefer the softer and lighter woods. For warming purposes the best adapted are the heavy woods, that are not reduced to ashes at once, but form large masses of glowing charcoal, and which do not crackle and splutter or emit clouds of black pungent or malodorous smoke.

In the Himalayas the resin-gorged wood of pine and deodar stumps is split up into chips and splinters, and burnt in a chafing dish in place of a lamp, giving out both light and heat. Dry bamboos, bruised so as to become full of numerous long cracks, burn like torches, and are so used by night travellers through the jungles. The green branches of the torch tree (*Ixora parviflora*) are also used for torches.

(2). *Wood burnt for the products of combustion.*

When wood is burnt (dry distilled) numerous substances are given off in the smoke and vapours, such as lighting gas, acetic acid, wood spirits, ether, creosote, tar, pitch, soot, &c., the quantity of these substances increasing with the temperature to which the wood is raised, *i.e.*, with the rapidity of the distillation. In the ashes, we have potash and various other salts. The woods that constitute the best fuel also yield the largest quantity of acid, small branch wood being the richest. Tar and pitch can be obtained in remunerative quantities only from resinous conifers. The destructive distillation of wood is usually effected in large iron vessels connected with a condenser. Tar and pitch may be easily made by heaping up the wood to be burnt in a pit, at the bottom of which there is a receptacle or a hole in communication with a receptacle. After being filled, the pit should be very nearly closed with sods, only a small opening in the middle being left in order to admit a sufficient supply to maintain the wood at a glowing heat. The wood should be split up small. As the wood burns the tar and pitch run down to the bottom and is thus collected.

## CHAPTER III.—FELLING AND CONVERSION.

IN utilizing a forest we must be guided by the extent of the usefulness and value of the produce it yields, and, so long as no injury accrues therefrom to the productive powers of the forest, also by the condition and demand of the market. As the circumstances of the market are very different according to the nature of the district and to the local manners and customs, these require to be very carefully enquired into and intimately known.

The subject of the present chapter will be studied under the following heads :—

- I.—Organisation of labour.
- II.—Agency by which work is carried out.
- III.—Tools employed in felling and conversion.
- IV.—Season for felling and conversion in the forest.
- V.—Felling.
- VI.—Conversion.
- VII.—Seasoning and stacking.

## SECTION I.—ORGANISATION OF LABOUR.

The productiveness of any industry is in direct proportion to the sufficiency, competence, and organisation of the labour engaged in it. In the case of forests the efficiency of the labour employed in realising its yield not only determines the extent to which the products turned out satisfy the requirements of the market, but also influences the amount of outturn in money as well in produce, and not unfrequently even the success of the treatment adopted. The men must be tractable, sober, industrious, strong, hardy, and enduring, inured to the climate, accustomed to life in the forests, and thoroughly skilful in the use of their tools. India has this great advantage over most other countries in that its labouring population being almost purely agricultural, nearly everyone from his boyhood is more or less expert with the axe.

The best men to get, if they are otherwise suitable, are those living inside or immediately round the forests. Such people are from their childhood accustomed to a forest life, are not afraid of wild beasts or the climate, know the trees and their characteristics, and, from long familiarity with the place, take an interest and often a pride in the welfare of the forest to which feeling imported

men cannot but be strangers. Moreover, they are available at any moment during the slack season for agriculture, and are hence also not so costly as imported labour. If such men can always look forward to having remunerative work to do during the time they are not engaged in their fields, they associate themselves cordially with the forest establishment and become a very effective addition thereto for the general conservancy and protection of the forest. As a rule, the aboriginal tribes, such as the Gonds, Bhils, Kols, &c., are the best adapted for the purpose; they are not only most amenable to discipline and control, but, depending to a very great extent for their livelihood on the produce of the forests and on the work therein, they are also more willing and expert workmen. The effectiveness and cheapness of local labour is singularly increased by according to the people who come to work small privileges which cost the owner of the forest little or nothing, such as grazing for a limited number of cattle, removal of a few head-loads of firewood, and minor produce, &c., either free or at nominal rates.

An indispensable condition for a sufficiently numerous body of well-trained woodmen is regularity and continuity of annually recurring work; but with local labour available, sudden unforeseen demands for mere axe-men can nearly always be met without difficulty. It is, however, otherwise when sawing work has to be done, knowledge of the use of the saw being, from caste and other prejudices, practically confined to the carpenter class. Hence a body of local sawyers cannot be trained and maintained without regular annual work.

In case local workpeople are wanting or are insufficient, the whole or part of the labour must be imported. If it is possible to get the new men to settle down with their families permanently in the locality, this should be done, otherwise inefficient men will have to be employed or a heavy compensation, in the shape of high wages, must be paid to good men for the journey to and fro, and for long absence from their homes, especially if they are townspeople. Another great drawback inseparably connected with imported labour, unless work is steady and continuous and on a sufficiently large scale, is the difficulty and sometimes impossibility of obtaining it in adequate quantity.

Whether the labour is local or imported, the men may be paid either by the day (*daily labour*) or by *piece-work*. The latter system has always this advantage, that it is cheaper—often very much cheaper; on the other hand, as it holds out a temptation to work hurriedly, its results are not always satisfactory. Moreover, it can

be adopted only when the quantity and quality of the work turned out can be rigidly tested and gauged. The cutting back of coppice and the execution of cleanings and thinnings are best done by daily labour.

Whether the men are paid by the day or by the amount of work done, they should be divided into gangs, each under a headman or master-workman elected by the gang and approved of by the employer. The headman should, in the case of daily labour, be paid somewhat higher wages than the rest of the gang, and he should be responsible for all his men. The gangs should be just large enough to be within the control of a single man ; and hence it should also not be too small or there will be waste of power.

The amount of work to be done will often vary above a certain known minimum. This minimum will fix the permanent strength of the combined gangs, and for any work above this minimum occasional workmen must be employed. These occasional men are best distributed amongst the existing gangs and not organised into separate gangs—a plan that will obtain from each headman the greatest amount of usefulness of which he is capable, and keep up every gang at its highest point of efficiency, by making the new men work side by side with those who have been accustomed to it, and by enabling the employer to get rid of inferior men without weakening or breaking up his gangs.

No organisation can be successful unless there exists a definite set of working rules, which prescribe the working hours and days, the kind of work to be done, the rates to be paid, the mode and days of payment, the obligations of the workmen, the punishments to be inflicted for infringement of those obligations, and the special concessions, if any, accorded by the employer during good behaviour or under certain specified circumstances. Under the head of obligations of the men, enter, among other things connected directly with their work, the following matters :—Their camping grounds or villages, as the case may be, sanitary arrangements, abstention from avoidable injury to the forest or forest area, immediate report of injury by others, liability to be called out to extinguish forest fires, or to help the establishment in tracking and arresting offenders, and so on. The punishments may take the form either of forfeiture of wages earned or of longer hours, or of curtailment of privileges, without prejudice, in serious cases or to deter habitual offenders, to prosecution under the forest or other law. Among necessary concessions due from the employer are payments to sick men, especially sufferers from accidents; advances under certain circumstances; special rewards for extra good work; arranging for sup-

plies of food if otherwise unobtainable, even to the extent of bearing part or whole of the cost of carriage ; concessions of timber and grass for building huts for the men, and of firewood for cooking or warming purposes. In the case of large operations giving steady employment all the year round, the employer may establish villages for his workpeople and their families, granting each family or household some land for cultivation at low rents and the privilege of grazing free, or at special rates, a fixed number of cattle. Furthermore, he may raise and maintain a Provident Fund, to which each workman will be bound to contribute, and he may establish primary schools.

#### SECTION II.—AGENCY BY WHICH WORK IS TO BE CARRIED OUT.

The work of felling and conversion may be carried out either by direct agency of the owner of the forest (departmental agency as it is called in the case of the State being the owner) or by the purchaser of the standing produce. The former method is obviously the one which offers the best guarantee of effectiveness from the point of view of conservancy and treatment, if well organised under the direction and supervision of experienced, energetic, and honest men who are in close and constant touch with the fluctuating affairs of the market. The system also saves to the owner a part or the whole of the profits that would otherwise fall to the wholesale purchaser of the standing unconverted material. This is especially true in the case of the private owner who gives his personal attention to the working of his forests.

In the case, however, of State forests or of forests belonging to corporate bodies, the entire directing and supervising agency is necessarily hired, and hence the requisite industrial activity and zeal is nearly always wanting, and even if they are present, the inevitable red tape, with its attendant hundred checks and ceaseless circumlocutions, kills all initiative, damps ardour, and renders the working agency at best but a sluggish machine. Moreover, corruption not unfrequently eats into profits, and may even make a possible paying forest a losing or unworkable concern. Lastly, owing to the peculiar constitution of the departments which together comprise what we call the Government, favouritism (for those who confer appointments have no private interests at stake), and the essentially permanent nature of service in any of those departments (except in the case of notorious dishonesty or gross incompetence or carelessness), unsuitable men, contrary to the custom of private managers or proprietors, are retained and entrusted with important duties and large powers, which they exercise to the detriment of the State. Hence the economical superiority of State over private agency in felling and conversion operations is more often apparent

than real, especially in a country of almost pure officialism such as India is.

In any case, private agency alone can be resorted to (1) when the money returns are not expected to cover the cost of felling and conversion, except in the few instances when the State may have to work at a loss in order to open the way to private enterprise; or (2) when only a few scattered trees possessing special characters and hence commanding specially high prices can be sold; or (3) when the annual coupe is divided into small lots either for convenience of supply, or because, owing to the poverty of the district, large and wealthy dealers do not exist; or (4) when the trees are surrendered to right-holders; or (5) when the establishment is too weak to undertake anything beyond merely seeing that the forest suffers no harm from the felling and conversion operations; or (6) when the consumers in the immediate neighbourhood of the forests are so poor that they require only small quantities of firewood and small timber, which, from not being able to pay others, they must cut and convert themselves.

On the other hand, the agency of the owner alone can be employed in cleanings and thinnings, since in both these operations the selection of the stems to be cut and their removal must proceed *pari passu* with one another. In after-fellings also, when serious damage is to be feared for the new generation, private agency should, as far as possible, be avoided for the felling and rough conversion of the trees.

### SECTION III.—TOOLS EMPLOYED IN FELLING AND CONVERSION.

These tools, according to the purpose for which they are used, are—

For cutting down saplings and small poles, ... ..	{ Bill-hooks ( <i>Fig. 18</i> ), light axes ( <i>Fig. 23</i> ).
For cutting down trees above the ground, ... ..	{ Felling axes ( <i>Fig. 20</i> ), cross-cut saws ( <i>Figs. 33, 34, and 37</i> ).
For felling trees by the roots and for grubbing out stumps,	{ Felling axes ( <i>Fig. 20</i> ), grubbing axes ( <i>Fig. 25</i> ), grubbing chisel, levers ( <i>Figs. 43 and 46</i> ), the screw-jack ( <i>Fig. 45</i> ), windlass, derricks, winches.
For directing the fall of trees,	{ Chains, levers ( <i>Figs. 43 and 46</i> ), the screw-jack ( <i>Fig. 45</i> ), thrust-pole ( <i>Fig. 44</i> ).
For lopping and topping and logging, ... ..	{ Felling axes ( <i>Fig. 20</i> ), cross-cut saws ( <i>Figs. 33, 34, 37, and 39</i> ).
For dressing or cutting up small wood, ... ..	{ Bill-hooks ( <i>Fig. 18</i> ), light axes ( <i>Fig. 23</i> ), frame cross-cut saw ( <i>Fig. 38</i> ).
For splitting ... ..	{ Splitting axes ( <i>Fig. 24</i> ), wedges ( <i>Fig. 41</i> ).



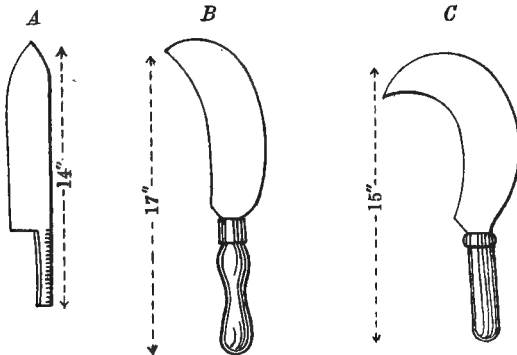
For moving logs, ... .. Levers (*Fig. 47*).  
 For dressing or rough-hewing }  
 logs, ... .. } Trimming axes (*Fig. 22*).  
 For converting logs, ... .. Saws (*Figs. 34, 35, and 36*).

It will be most convenient to describe the various implements in the following order:—(1) bill-hooks, (2) axes of all kinds, (3) saws, (4) other grubbing tools, (5) tools for directing the fall of trees, and (6) other tools.

#### ARTICLE 1.—BILL-HOOKS.

The most suitable forms of this tool are represented in *Fig. 18*.\* Bill-hooks are used principally for cutting down thin stems, which

*Fig. 18.*



*Bill-hooks ( $\frac{1}{15}$ th original size).*

cannot stand the shock of an ordinary axe, and for trimming off small branches and preparing faggot wood. They require less room to swing than axes, and are therefore more convenient to use in dense young growth; but in the exploitation of bamboo clumps their short handle and long blade are not so suitable as light one-hand axes to be described lower down.

#### ARTICLE 2.—AXES.

All axes agree in consisting of a *head*, in the *eye* of which one end of the *handle* or *haft* is fixed. The portion of the head from the cutting edge to the eye is called the *blade*, that on the opposite side being the *back* of the axe. The head may be entirely of steel, or of iron edged with steel (the more usual case, as steel is quite unnecessary except at the edge). The temper of the edge must be exactly suited to the hardness of the wood to be cut. If the

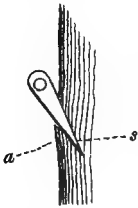
\* Information regarding "dahs" used in Burma and North-East India is wanting and would be gratefully received.

steel is too highly tempered, it will break; if not sufficiently tempered, the edge will be turned. Soft-wooded trees require a higher temper than hard-wooded trees.

### 1. *The felling axe.*

**ACTION OF THE AXE.**—The action of an axe is to *sever*, to *crush*, and to *shear*. The severing and shearing actions are in direct, the crushing action in inverse, proportion to the sharpness of the edge and the thinness of the blade combined. When an axe is driven at right angles to the fibres, there is no shearing action at all, only severing and crushing; but when the blow is delivered

**Fig. 19.** obliquely, all three actions take place and the axe produces its greatest effect. Another reason why the obliquely driven axe penetrates further is that the lower lip of the wound it makes (see *a* in *Fig. 19*), bends easily downwards and thus widens the gape, so as to allow the blade to continue its onward motion; whereas when the cut is perpendicular to the axis of the tree, the severed fibres have to be crushed away longitudinally to produce a wider opening for the entry of the thicker hind portion



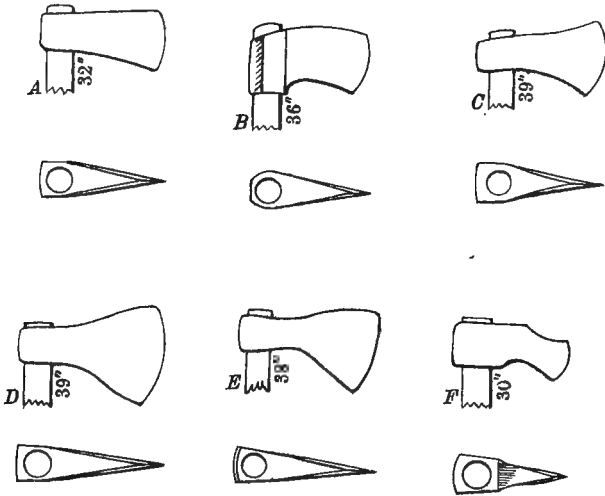
of the blade into the wound.

**WEIGHT OF THE AXE-HEAD.**—This of course depends to some extent on the strength of the axe-man, but it is essentially regulated by the degree of hardness of the wood to be cut and the size of the tree to be felled. The softer the wood, the more easily are the fibres crushed and displaced, and, as a rule, also separated from one another, whereas in hard wood the axe can do very little crushing and comparatively little splitting, and must hence act chiefly by severing. Hence hard woods require a lighter and thinner-bladed axe than soft woods. Very light thin-bladed axes must be used with small poles and saplings in coppice fellings to save the roots from violent shocks and consequent rupture, and also whenever the stem is so thin and pliant as to yield before the blow from a heavier axe. Thus the weight of the felling axe for anything above small poles varies from  $1\frac{1}{2}$  to  $3\frac{1}{2}$  lbs., the latter limit being attained in the conifer forests of the Himalayas. For a stem having a greater diameter than 6 inches the weight of the axe should not be less than 2 lbs. For the special case of thin yielding stems and of small poles in coppice fellings the weight should be about 1 lb. more or less.

**SHAPE OF THE HEAD.**—The shape of the axe-head is extremely varied, especially in India, where no machinery is employed in the

manufacture and the smith follows his own sweet will so long as the product of his handiwork bears a general resemblance to the model he is imitating. Information on this point is, therefore, very scanty, and hence in *Fig. 20* below only a few good patterns of axe-heads used in India are reproduced.

Fig. 20.



Some good Indian felling axes ( $\frac{1}{10}$ th original size). *A*, Nimar pattern (up to 2½ lbs.). *B*, Amritsar pattern (up to 3½ lbs.). *C*, *D*, and *E*, North-West Himalayas (up to 3½ lbs.). *F*, Gond pattern (up to 2½ lbs.).

In some axes the cutting edge forms a perfectly straight line, but a slight curve is always to be recommended: *firstly*, because in a straight edge there is risk of the nearer corner striking the wood first and breaking off, whereas, when the edge is curved, the middle of the curve, which is the strongest portion of the edge, always strikes and enters the wood first, and is followed by the rest of the edge; and, *secondly*, because, as a consequence of this last mentioned fact, a curved edge penetrates deeper.

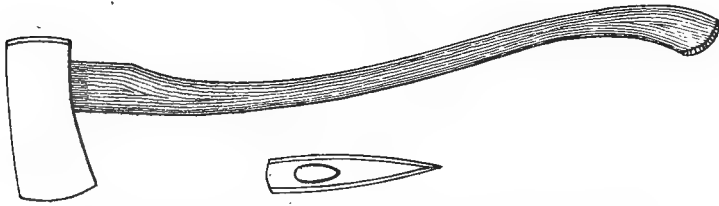
The width of the edge will depend on the hardness of the wood. The harder the wood is, the narrower must be the blade, in order to secure effective penetration.

In every good felling axe the weight should be accumulated principally just in front of the eye, so as to give it as much steadiness as possible in the stroke. Such a disposition of the weight also permits of the faces of the blade being made slightly concave or at least perfectly straight. This fact is of no slight importance, with

respect to penetrative power, in our Indian axes, as otherwise, the eye being circular, the blade would taper down too abruptly.

The eye may be either circular or oval (the narrower extremity being directed towards the edge). The opening of the eye is not the same throughout, but is widest at the further end in order to prevent the head from slipping off the handle. An oval eye (*Fig.*)

Fig. 21.



*Felling axe with oval eye and curved handle ( $\frac{1}{8}$ th original size).*

21) secures greater rigidity for the handle, distributes the weight properly by enabling an even taper to be maintained, and, as shown in the next paragraph, also enables the axe-man to deliver a steadier stroke. *Per contra*, it has two disadvantages as compared with a circular eye: the handle requires some skill to prepare, and as it must be put into the eye by the lower extremity, it can be fixed tight only by means of a wedge driven into a slit, which is obviously a source of weakness, and from which the wedge has a constant tendency to slip out. In India the eye is always circular.

**THE HANDLE.**—According as the eye is circular or oval, the whole of the handle is round or the lower quarter or fifth of it is flat. In the latter case the woodman, having flat surfaces to feel with his right hand (with which he directs the blow and which he slides down to near his left hand as the axe descends) can aim a much steadier blow than when a completely cylindrical object, the feel of which is the same whatever its position is, slips through his hand. An oval section near the axe-head also gives the handle greater dimension parallel to the blade just where greatest transverse strength is required. Lastly, and this is a matter of prime importance, a round handle is liable to work round in the eye and thus destroy the entire effect of a stroke, besides possibly causing the edge to be turned or broken. On the other hand, a round handle is easily obtained, being merely a straight branch or stem or solid culm, the lower end of which is just too thick to pass through the eye (if it is a hard knot, so much the better), and on this account requires no wedging at all to keep it in place.

The handle is usually straight—in India always so—but a handle of the shape represented in *Fig. 21* gives the axe-man a better grip with his left hand and is easier for his right hand.

The length of the handle varies from  $2\frac{1}{2}$  to  $3\frac{1}{4}$  feet. For very hard woods it should not exceed 3 feet.

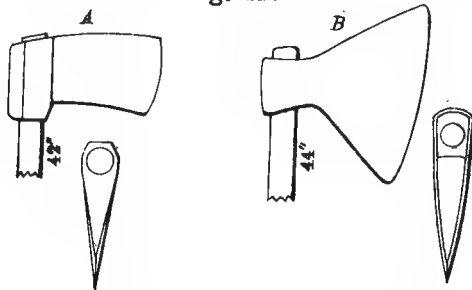
In round handles the fibres at the thick end are apt to get crushed in the eye, eventually allowing the head to slip off. This is effectually prevented by protecting the last inch or so of the handle with a strip or two of thin sheet iron or copper, which gets jammed between the wood and the iron head and renders any movement of the latter impossible.

Information regarding the best woods for axe handles is wanting. In Central India and in the plains of North-Western India *Anogeissus latifolia*, species of *Grewia*, *Zizyphus Jujuba*, and *Dendrocalamus strictus* are chiefly used. In the North-West Himalayas *Cotoneaster bacillaris* furnishes handles that last up to two and even three years.

## 2. The trimming axe.

The trimming axe serves to remove the branches of fallen trees and to dress and rough-hew logs. The same axe with which a tree was felled will do equally well for trimming off branches, but for all large branches and for dressing logs a heavier axe with a broader blade is much more serviceable. Indeed, in dressing fallen timber the axe is best swung vertically in order to secure the full amount of momentum, and its weight may hence be as much as the axe-man can control. In the conifer forests of the Western Himalayas the weight often runs up to 8 lbs., and even more. To gain additional momentum long handles are used, the length ranging from  $3\frac{1}{2}$  to  $4\frac{1}{2}$  feet. In *Fig. 22* are reproduced two patterns

Fig. 22.



Indian trimming axes ( $\frac{1}{10}$ th original size).

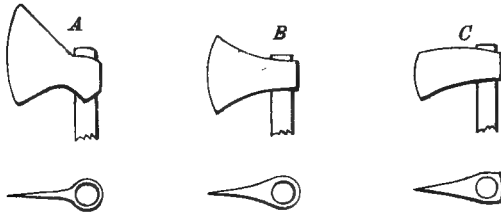
A.—Amritsar pattern (up to 6 lbs.).

B.—North-West Himalayas (from 6 to 9 lbs.).

of Indian trimming axes. Although the advantages of using special trimming axes are unquestionable, yet woodmen in most parts of India actually do all their work with the ordinary felling axe alone.

Under this head may be mentioned the light, broad, thin-bladed, one-handed axes (hatchets) used for lopping off small branches and for topping off saplings and cutting bamboos (*Fig. 23*).

**Fig. 23.**



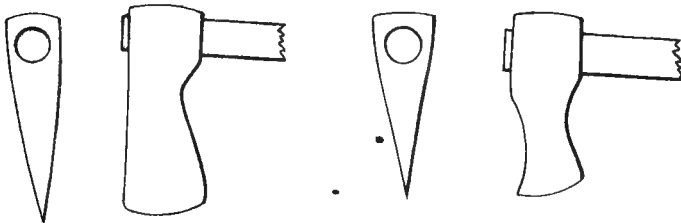
*Light one-handed axes ( $\frac{1}{10}$ th natural size).*

*A and B.—Used in North-West Himalayas. Weight, 12 ounces.*

### 3. *Splitting axes.*

These axes, as the name implies, are used for splitting up thick billets or large rounds into sections. Their action is thus almost purely a shearing one. Hence they need not be so sharp as the two descriptions of axes already described, but they should be as heavy as the heaviest trimming axe. Contrary to the rule for those axes, their weight should lie all round the eye in order to give them as much driving power as possible. As they are often used as hammers for driving in wedges, there should also be plenty of metal in the back. A slight convexity of the faces of the blade is not objectionable as long as the taper near the edge is sufficient. *Fig. 24* represents two useful patterns of splitting axes.

**Fig. 24.**

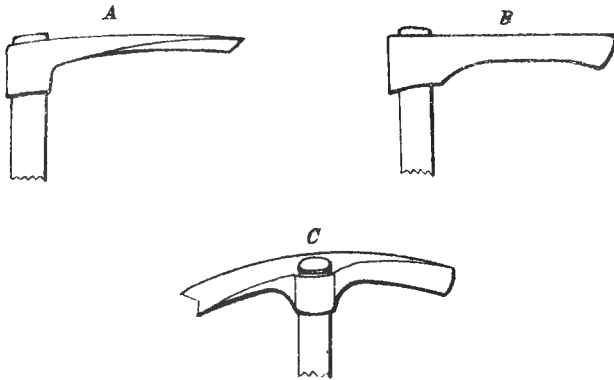


*Splitting axes ( $\frac{1}{8}$ th natural size).*

4. *Grubbing axes.*

Grubbing axes serve the double purpose of digging up the soil round roots and severing those which do not exceed 3 or 4 inches in diameter. The blade should always be slightly curved, and about 12 inches long and from 2 to 4 broad at the edge. *Fig. 25* represents three effective forms.

Fig. 25.

*Grubbing axes* ( $\frac{1}{10}$ th natural size).

## ARTICLE 3.—THE SAW.

The saw consists of a thin, comparatively broad blade or plate of steel, one edge of which is toothed. The saw is essentially a tool for use across the fibres of the wood. If the fibres of wood were perfectly parallel and there were no discontinuity due to branches, knots and other causes of transverse or irregular growth, then all longitudinal separation would be effected by tools acting solely on the principle of the wedge. It is because of such discontinuity that the saw is also used for cutting wood longitudinally, *ripping* as it is technically called.

The following are some of the technical terms used in connection with saws:—

*Rake*, the inclination of the line of the teeth, in a straight saw, to the direction in which the saw moves.

*Space*, the distance from tooth to tooth measured at the points.

*Face* of a tooth, the profile of the tooth *facing* the side towards which the saw moves in cutting.

*Back* of a tooth, the opposite profile.

*Gullet* or *throat*, the extent of opening between two successive teeth.

*Gauge*, the thickness of the saw.

*Set* or *bent set*, the extent to which the teeth are bent to either side of the plane of the blade.

*Straight set*, when the teeth lie entirely in the plane of the blade.

*Pitch*, the angle formed by the face of a tooth with the line passing through the points of the teeth.

*Kerf*, the thin plate of wood removed by the saw in the form of *sawdust*.

Other technical terms will be explained as they occur.

**ACTION OF THE SAW.**—For the sake of clearness we will assume that the saw works across the fibres. A perfect saw makes its way through the wood by combined *cutting*, *tearing*, and *shaving*. Suppose *A*, *B*, and *C* in *Fig. 26* to represent the faces (considerably enlarged) of three consecutive teeth, *A* and *B* being filed obliquely

Fig. 26.

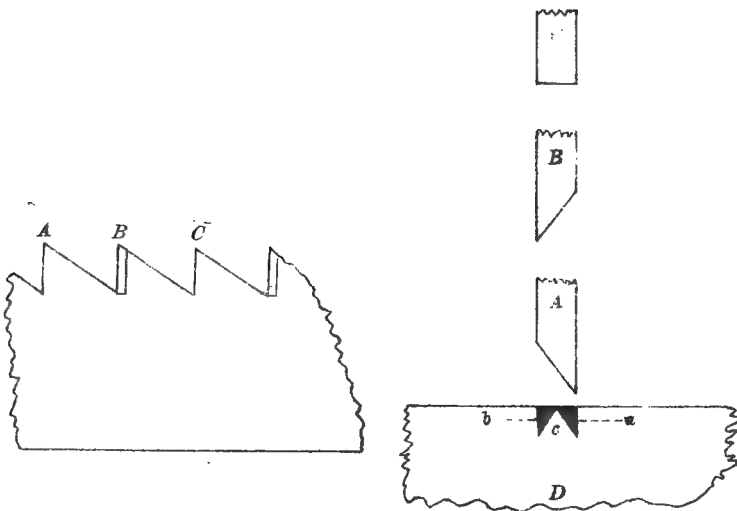


Diagram illustrating action of the saw.

to an edge on different sides, while *C* has an edge equal in width to the thickness of the blade. As the saw moves forward, *A* clears in the wood *D*, the opening *a* partly by cutting, partly by tearing asunder the fibres which come in its way. Similarly the tooth *B* clears in its passage the opening *b*. The triangular portion *c* left between *a*



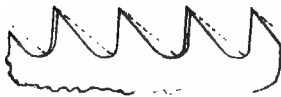
and *b* is then shaved off by the broad edge of the tooth *C*, which is hence designated a *clearance* tooth. In the preceding explanation we have supposed only one tooth of each kind acting, but actually the opening *a* may be made by two or more teeth following in succession; and similarly the opening *b* by as many teeth filed away in the other direction, while a single clearance tooth suffices to remove the section of the fibres between *a* and *b*. The action of the saw is greatly facilitated if each clearing tooth shaves off only a portion of the section left by the cutting teeth that precede it. This end is secured by making the clearing teeth slightly shorter than the other teeth. In India the faces of the teeth are never filed to an edge, and the action of the saw is consequently reduced to simply tearing and shaving, or, to use a simple and more expressive term, to rasping.

The portions of fibre torn and shaved off (the sawdust), unless they were at once removed out of the way of the saw, would interfere with its passage, and, by coming between the blade and the cut surfaces of the wood, eventually cause it to jam (*buckle*). Hence the necessity of making the gullet large enough to afford sufficient room to hold the sawdust until it falls out as the saw continues to advance.

SHAPE OF THE TEETH.—A great variety of shapes have been devised, especially in America, where the saw is better understood than in any other part of the world. For us, who have to work in a backward country like India, it will suffice to note only a few of the principal forms.

If a saw is required to cut in one direction only, the teeth have the well-known form approaching more or less nearly that of a right-angled triangle. The pitch of the teeth may vary from  $80^{\circ}$

Fig. 27.



*Rounded gullet.*

to  $100^{\circ}$ , according to the softness of the wood. It is usually high in circular saws on account of their great speed.

If the quantity of sawdust is large, the gullet is enlarged by hollowing out the back of the teeth and giving the bottom of the gullet a curved outline (*Fig. 27*).

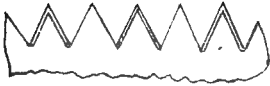
Such an outline is an advantage under

all circumstances, as it prevents any tendency of the blade or teeth to crack.

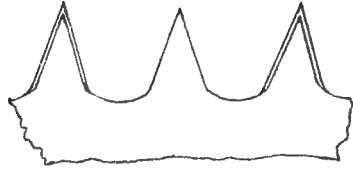
If the saw has to cut in both directions, the teeth must assume the form of isosceles triangles, the bottom of the gullet being, according to the quantity of dust to be cleared, either

an angle (*Fig. 28*), or a curve (*Fig. 29*), or a straight line (*Fig. 30*).

**Fig. 28.**



**Fig. 29.**



**Fig. 30.**



A very powerful combination of the two preceding forms, which is of American design, is the M tooth (*Fig. 31*).

**Fig. 31.**



*M-teeth.*

Sawdust occupies from four to six times the space it did in the wood, the proportion being greatest in the case of soft and porous woods. The height of the teeth should, therefore, always be considerably greater than the depth cut through at each movement or revolution of the saw, so as to increase the depth of the gullet. Hence the softer and looser grained the wood is, the longer will be the teeth. Greater capacity can be secured for the gullet also by a wider spacing of the teeth, and actually the wideness of the spacing is determined by the softness and porosity of the wood; but it has been found from experience that the force required to move the saw increases with the fewness of the teeth, so that a limit is

fixed for the spacing, which ought never to be exceeded. In the case of hard woods the necessity of close spacing is further accentuated by the fact that each single tooth can do comparatively little work, and that consequently the more numerous they are, *i.e.*, the closer the teeth, the more effective is the saw. Hence the superiority of M teeth and other similar forms, which increase the number of teeth for a given length of blade.

The angle between the two profiles of a tooth may vary between  $70^\circ$  and  $45^\circ$ , being about  $45^\circ$  to  $50^\circ$  for very soft woods and  $65^\circ$  to  $70^\circ$  for very hard woods. Hence, since we know that the number of teeth must increase with the hardness of the wood, saws for very hard woods should always have teeth in the form of isosceles triangles, and should hence cut when drawn in either direction.

The line passing through the points of the teeth (clearance teeth alone obviously excepted) should be an even line; that is to say, some teeth should not project beyond others, otherwise the former alone will do the work and the cutting power of the saw will thereby be diminished. This proviso being satisfied, the length of the teeth need not always be the same. There are many woods so constituted that in cutting them the saw can be moved only with difficulty at the commencement of each cut, and there is much splintering and tearing of the wood if the cut is commenced with coarse teeth. To obviate this drawback, the size of the teeth is gradually increased, so that the finest commence the cut and the coarsest finish it.

The teeth should be filed away on one side to a sharp edge. If the saw is to cut in one direction only, the face alone should be so filed (see *Figs. 26 and 27*); if in both directions, both profiles of the teeth should be sharpened (see *Figs. 28, 29, and 30*). Alternate teeth should have their sharp edges on opposite sides. The Indian sawyer nearly always neglects to give the teeth of his saw any sharp edge at all, probably in order to diminish wear; but against this diminished wear must be set the much greater loss he suffers from the smaller quantity of work he turns out.

**SET OF THE TEETH.**—The teeth are given a set in order to enable them to clear in the wood a passage wide enough for the blade of the saw to pass through without any tendency to buckling. The softer or more coarse-fibred or gummy or resinous the wood, the stronger must be the set; but it should be just strong enough to serve its purpose, otherwise there is waste of wood due to too thick

a kerf, and the teeth get worn away unnecessarily quickly, and the surfaces cut are unnecessarily rough. The strongest setting should not increase the width of the cutting edge to more than double the gauge of the saw. As a rule, ripping saws require very little set, since the two sections, from the wood in the interior being moister, bend away outwards and make room for the saw. The set should be uniform throughout the length of the saw, for if one tooth projects sideways beyond the rest, besides that it will become worn much quicker, it will also scratch the wood and produce a rough

Fig. 32.



Saw-set.

surface. The set should be the same on both sides, otherwise the saw will cut more freely on the side of the stronger setting and have a tendency to run towards it. The Indian sawyer sets the teeth of his saw either by blows or by leverage with a hand saw-set (*Fig. 32*).

The teeth should be set alternately to different sides—a very obvious warning, but one which our sawyers very often neglect.

In a bent set each tooth can cut on only one side, and generally the teeth have a tendency to spring in and are more subject to side strains. To obviate these defects the *spread* set has been devised, in which the points of the teeth are flattened out so as to become broader than the rest of the blade. This kind of setting is perhaps too advanced for introduction into India.

**THE BLADE.**—The gauge of a saw ought to be only just sufficient to give it the requisite stiffness. The disadvantages of a thick-bladed saw are that it requires more set, is in need of more frequent sharpening, is more difficult to file, wastes more wood, and, being heavier and cutting a wider kerf, is more fatiguing to use. If the blade is too thin, the saw is liable to twist and make an uneven kerf, the result being buckling. The Indian method of filing the teeth, so that they cut when being drawn towards the operator, permits of the use of much thinner blades than the English method, which makes the saws cut in thrust. Saws are sometimes made thickest along the cutting edge and become gradually thinner towards the back. This is in order to dispense with the necessity of any set at all.

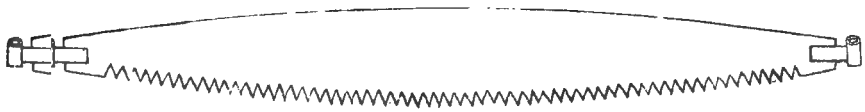
In order to reduce friction to a minimum, the blade should be as smooth as possible, and its width should be no more than what is required to prevent it from bending in its own plane. The

smoother and more uniform it is, the thinner and narrower a saw you can use. A smooth blade is also less liable to rust. To diminish the friction, most saws are made gradually narrower towards one extremity. Some cross-cut saws are made broadest in the middle (*Fig. 33*), not only with a view to minimise friction, but also in order, without using too much metal, to place most of the weight where it is required.

When stiffening frames (*Fig. 36* and *38*) are used, both the thickness and width of the saw are reduced to a minimum.

The cutting edge is very often made on a convex curve (*Fig. 33*), or with a "crown" or "breast" (*Fig. 34*), to adapt it to the

**Fig. 33.**



*Curved Cross-cut Saw.*

**Fig. 34.**



*Delhi Saw.*

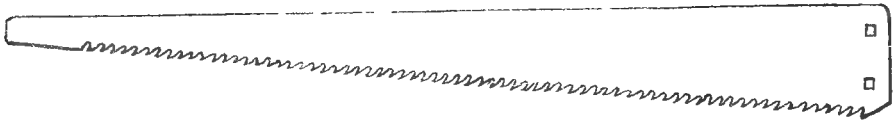
natural rocking motion of the hand and arm.

A saw should be springy and elastic and at the same time highly tempered. A soft saw dulls sooner, drives harder, and does not last so long as a hard saw. Nevertheless saws of Indian manufacture are often made of merely tough iron.

In a straight saw the rake influences the pressure of the saw on the wood during the progress of cutting. The rake should therefore be regulated according to the hardness of the wood to be sawn and the height and pitch of the teeth.

THE MORE COMMON FORMS OF SAW USED FOR FOREST WORK IN INDIA.—These are the ordinary pit saw (*Fig. 35*) and the frame

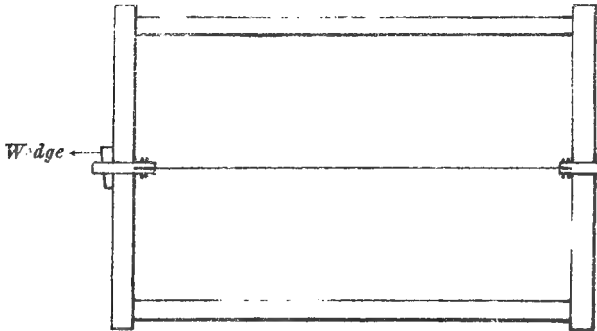
*Fig. 35.*



*Pit Saw.*

saw (*Fig. 36*) for longitudinal cutting ; the curved cross-cut (*Fig.*

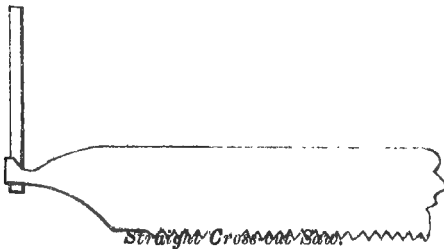
*Fig. 36.*



*Frame Saw for longitudinal cutting.*

33) and straight cross-cut (*Fig. 37*) saws for felling and logging ; the frame cross-cut saw (*Fig. 38*) for cutting up into billets ; and

*Fig. 37.*

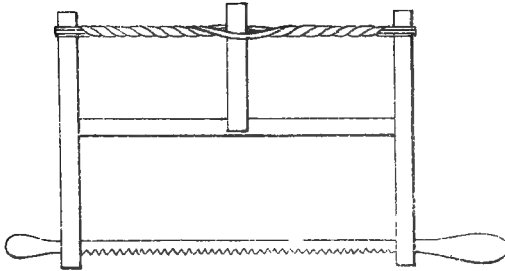


*Straight Cross-cut Saw.*

the Delhi saw (*Fig. 34*) for all three purposes. In the Western

Himalayas and in the Punjab a straight one-hand saw about

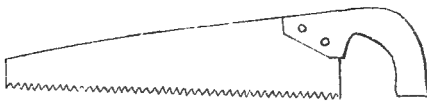
Fig. 38.



*Frame Cross-cut Saw.*

3 feet long (*Fig. 39*), like an ordinary ripping saw, is used for logging. It is, however, a very ineffective tool, and when a tree is

Fig. 39.



*Rude one-hand Cross-cut Saw.*

more than about  $2\frac{1}{2}$  feet in diameter, it has first to be split down the middle with wedges. There is no reason why the American one-man saw

(*Fig. 31*) should not be at once introduced as a substitute. It works very quickly and cuts both ways.

The use of the circular saw for conversion in the forest is too restricted in this country for a special description of it to be introduced here.

In logging fallen trees a curved cutting edge offers several most important advantages: it suits the natural rocking motion of the hands and arms of the men, it requires less force to pull the saw (since the teeth come successively into action one by one, never several together), the sawdust is never an obstruction (since it is at once cleared), the saw can cut down to the very bottom of the log without risking the teeth against the ground or requiring the log to be raised off the ground, and the operators' hands are always well above the ground and cannot therefore be hurt.

In felling also a curved edge is to be preferred, as it causes very much less fatigue.

In longitudinal cutting, a curved saw, besides suiting the natural motion of the hands and arms, is easier to pull, cuts deeper at each stroke, enables the bottom sawyer to stand or kneel well away from the falling sawdust, and can be used to cut with right down to the ground.

In the use of both the curved and the frame saws for longitudinal cutting the logs have to be raised off the ground only at one end, whereas, when the pit saw is employed, owing to its great length, the logs have either to be entirely lifted off the ground on two high supports or placed on supports resting across a long deep pit. The curved Indian saw, owing, no doubt, to its very rough manufacture, offers the very serious drawback of leaving a very uneven surface.

HOW TO SELECT SAWS.—A few general directions will prove useful. First of all try the blade by springing it; it should be elastic, and stiff enough without being too thick. The thinner you can get a stiff saw the better; also the narrower the better. Next see that it bends regularly and evenly from point to heel in proportion to its width at each place. In the third place, ascertain that the blade is ground smooth by examining it in different lights; the appearance of the surface should remain the same under changing lights. Then test the temper by bending one of the teeth with a sharp blow; if the tooth does not break, there is ample proof that the teeth will not break in use. Lastly, examine the colour and ring. The blade should by preference be of a dark colour, and when struck, should give a clear bell-like sound.

If the saw is a one-hand one, it should be well balanced when held in the position for cutting. Moreover, the handle should be made of strong, well-seasoned wood, should fit the hand properly, and should be firmly attached to the blade.

HOW TO MEASURE UP SAWING WORK.—A few words on this point are necessary, as it is not uncommon to read, even in printed official reports, of the amount of sawing done estimated in so many cubic feet! The work done by a saw is evidently the area of surface it has cut through—not the sum of the two surfaces, one on each side of the kerf, but the single surface, supposing the kerf to be a mathematical plane.

Nevertheless, in paying up sawyers, since slabs and other pieces fitched off, although they are taken off by the saw, are not deemed to be sawn goods, it is customary to measure up the *total* surface



of what comes under this designation. As a certain considerable amount of detailed measurement and calculation are necessary to get at this figure, a still simpler plan is pursued when a large quantity of goods of a single fixed scantling is prepared : the work to be paid for is ascertained in running feet. The simplest case of all would of course occur when the sawing was paid for by the *number* of pieces in each class of goods turned out. But none of these methods of measuring up work gives the real amount of sawing work done.

#### ARTICLE 4.—WEDGES.

Wedges may be made entirely of iron (*Fig. 40*), or of wood and iron combined (*Fig. 41*), or of wood alone (*Fig. 42*).

<sup>1</sup>  
Fig. 40.



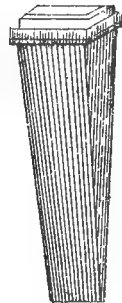
*Iron wedge.*

Fig. 41.



*Chisel-wedge.*

Fig. 42.



*Wooden wedge.*

Iron wedges are unnecessarily heavy and costly, and are therefore seldom used. They require to be driven with heavy wooden mallets.

The second class of wedges (*Fig. 41*) is very much more serviceable ; perhaps the most serviceable of the three. It is on the same principle as the ordinary Indian village chisel, the head, corresponding to the handle of the chisel, being of some hard, compact wood, strengthened with an iron ring round the crown. Both this and the next class of wedges are driven with the back of a heavy axe.

Wedges of the third class (*Fig. 42*) are shaped out of some hard

tough wood, the grain running with the length of the wedge. In conifer forests they are readily made out of the branchwood. If the wedges are carefully made from wood not immediately at hand, the head may be protected from splitting with an iron ring.

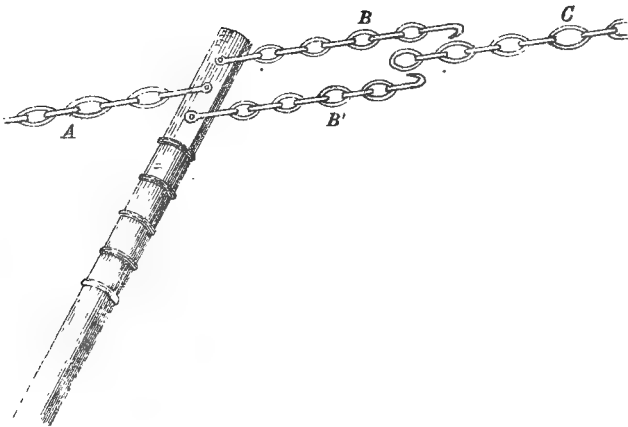
ARTICLE 5.—TOOLS FOR DIRECTING THE FALL OF TREES.

These are strong chains ending at either extremity in a hook attachable to any of the links, the *forest devil*, and an apparatus which may be termed the *thrust pole*.

The chains are used for hauling down trees in a given direction when they have been sufficiently cut through.

The forest devil (*Fig. 43*) consists of a strong pole about 6 feet

Fig. 43.



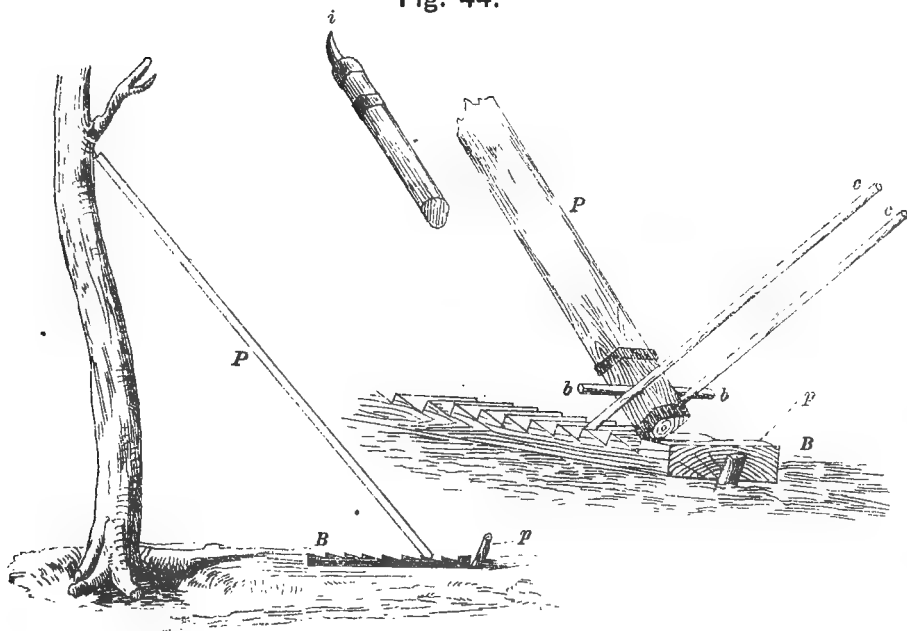
*The Forest Devil. (After Gayer).*

long, to which are fixed the three chains *A* (of indefinite length) and *B* and *B'* (of short length), and ending each in a hook that can be hitched on to any link of the free chain *C*, which is attached to the tree to be felled. The chain *A* is secured to a stump or standing tree. As the tree to be felled is pulled and sways forward more and more, the hooks at the end respectively of

*B* and *B'* are hitched forward alternately a link or two at a time, until the tree is completely pulled over.

The thrust pole (*Fig. 44*) consists of (i) a straight stout pole *P*,

Fig. 44.



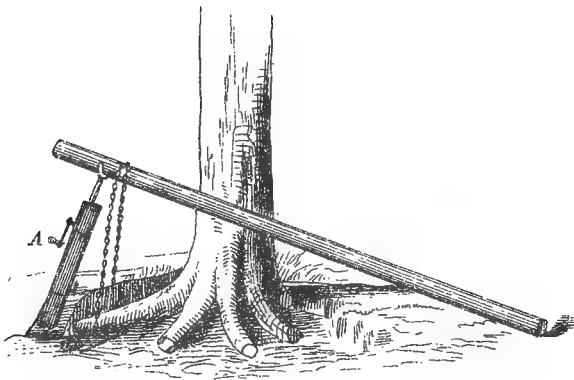
*The Thrust Pole. (After Gayer).*

the upper end of which is armed with a strong iron point *i*, while an iron bar *bb* passes through a hole a few inches above the lower extremity ; (ii) a block *B* of some hard tough wood, the upper surface of which is serrated, and which is prevented from moving backwards by the peg *p* driven into the ground ; and (iii) two crowbars or iron levers, *c, c*.

ARTICLE 6.—TOOLS FOR UPROOTING TREES AND STUMPS.

These tools comprise grubbing axes (already described on p. 81), grubbing chisels, the forest devil (already described on p. 92), the *stool-wrench*, the thrust pole (see above), and the screw-jack (*A* in *Fig. 45*).

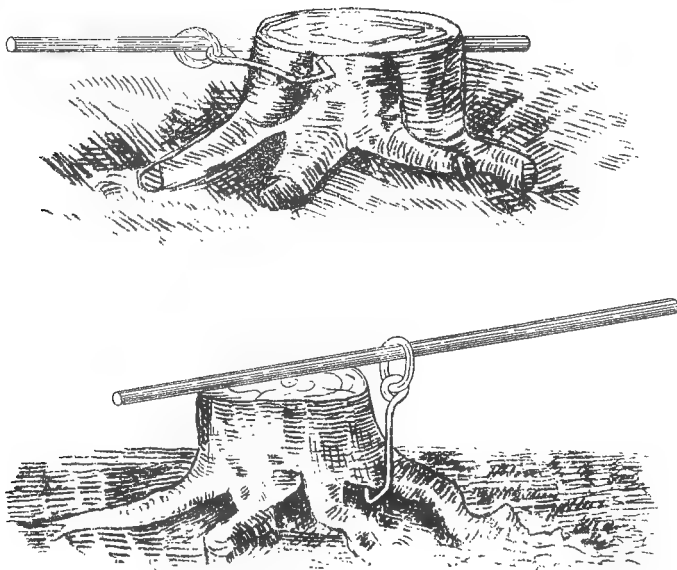
Fig. 45.

*The Screw-Jack. (After Gayer).*

A grubbing chisel is simply a long iron chisel edged with steel and used on roots that cannot be reached with a grubbing axe.

The stool-wrench (*Fig. 46*) consists of a strong hook *h*, which slides easily on a crowbar, *c*.

Fig. 46.

*The Stool-Wrench. (After Gayer).*

The screw-jack is well known to every one who has been at a railway station. Its employment, as well as that of the thrust-pole and stool-wrench, is sufficiently evident from the illustrations.

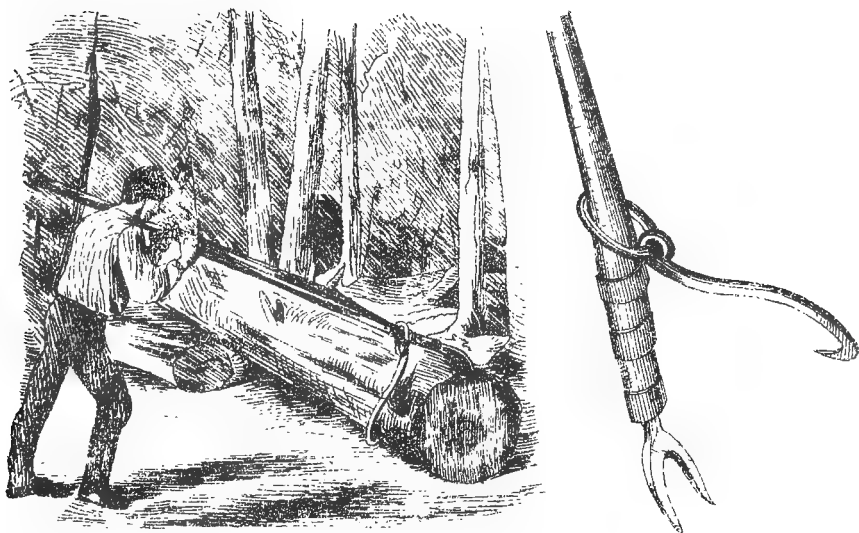
ARTICLE 7.—TOOLS FOR MOVING LOGS FOR CONVERSION.

The tools with which we are concerned here are only such as serve to move logs over short distances to points in the forest, and often even in the coupe itself, where they can be easily converted.

Rough tools always ready to hand are small round billets or poles on which the logs are rolled and sufficiently strong, short poles used as levers, with which they are rolled along.

A wonderfully convenient and effective tool for rolling logs along is what we may term the *hook-lever* (Fig. 47), an implement

Fig. 47.



*The Hook-Lever. (After Gayer).*

of German origin, which consists of a hook, similar to that of the stool-wrench, sliding on a stout pole that is shod with a two-pronged fork.

SECTION IV.—SEASON FOR FELLING AND CONVERSION IN  
THE FOREST.

(1). *Season for felling.*

On the season in which trees are felled depend the technical properties of the wood, and even the possibility of carrying out the work, for labour may not be available in sufficient quantity and at reasonable cost throughout the year, and malaria or heavy rain or snow may be a bar to all operations.

To prevent cracks timber should be allowed to season slowly. Hence it should be felled in damp and cool (if possible, even cold) weather. Where there is a true winter, felling in winter also preserves the wood from fermentation of the sap, from infection by fungus spores, and from the attacks of insects. With regard to durability alone, the theoretically best time for felling occurs when the trees contain their minimum of reserve materials (see page 25, para. 3), that is to say, generally just after the new flush of leaves is out. But this season can be observed only when it does not coincide with the appearance of new seedlings, which the felling and export operations are bound to destroy; or with the season of heavy rains, during which the ground would be soft and muddy and the advance growth, if there is any, full of tender and easily-injured shoots. It may of course be observed in coupes that are to be clear-felled and then re-stocked artificially. For the safety of young growth the best time for felling is the season of repose, when the plants are least fragile and possess their greatest recuperative power; but on the higher ranges of the Himalayas the snow lies too heavy for felling to take place then without risk to human life, and, as export must take place during the following summer, most of the trees have to be cut in spring, while the seedlings are only just sprouting or coming up from seed.

As regards firewood, we know that the quicker it dries, the better it is; also that it is heavier the more full it is of reserve materials. Hence in felling for firewood, the best time of the year, provided sylvicultural exigencies do not bar it, is when dry, warm weather prevails; and if this coincides with the season of repose, so much the better. The time for felling coppice is limited, by purely sylvicultural considerations, to this season, the only exception being when bark for tanning is the chief produce sought, in which case the felling must be effected during the first three or four weeks of the season of vegetation, unless the trees are barked standing, or this period falls within the rainy season. In the case of charcoal-making, the charcoal-burners must have a sufficiently long spell of

fairly dry weather in which to complete their work. Cleanings and early thinnings, in which the poles are cut as they are selected, must of course be effected while the forest is in full leaf.

The season when alone floating is practicable fixes the period within which wood that is to be removed by water must be cut. The condition of the market may also exercise a determining influence. For instance, purchasers who require a certain class of fresh-cut produce may offer themselves only at a certain time of the year.

Lastly, when the trees are to be removed by the roots, the work must be undertaken while the soil is still sufficiently moist to be easily dug.

The general conclusion to be drawn from what precedes is that the period for felling will always vary with the locality and climate and with the purpose to be served ; but, as a general rule, in the higher Himalayas, where heavy snow falls and lies, it will comprise the spring and early part of summer, while elsewhere it will extend over the cooler portion of the season of rest.

### (2). *Season for conversion.*

As a rule, the limited amount of conversion to which wood is subjected in the forest is effected *pari passu* with the felling operations, as such an arrangement economises labour and supervision, and every kind of conversion is effected most easily while the wood is green. But it may happen that the time in which the coupe must be cleared does not allow of the work being completed, and in this case only the roughest kind of conversion is permissible before the produce is removed to the nearest special conversion depôts.

When the market requires fresh-cut produce, the date on which delivery must be made and the time occupied in export fix rigidly the season for the conversion operations.

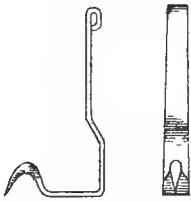
## SECTION V.—FELLING.

In felling a tree we have to keep in view three main objects—(1) realisation of the largest outturn in money or produce that it can yield, (2) facility, sometimes even possibility, of export, and (3) safety of the soil and surrounding forest.

In order to secure the first object, the timber-yielding portion of the tree should be preserved as intact as possible. Hence the bole of a heavy tree should not be allowed to fall across a hollow or across any projection, such as a ridge, rock, or boulder, or a fallen

tree. The bole of a tree will often break across owing simply to its strong ample crown striking the ground first. When this danger is apprehended, it will be necessary to lop off the larger boughs, or even remove the whole or the greater part of the crown. Such a proceeding will also cause the tree to fall much lighter. A very tall tree, like a deodar, pine, or fir, cannot, under any circumstances, be saved from breaking, and the only plan to adopt, when it is feasible, is to remove the upper portion of the bole in sections from the standing tree. For this purpose expert and fearless men, such as can be found in few places in

Fig. 48.



*Climbing Iron. (After Boppe.)*

India, must be obtained, and climbing irons used (Fig. 48).

On a slope, a tree falls through the smallest angle, *i.e.*, with least momentum, if felled towards the hill; but unless the tree is well secured, there is danger for the workmen as well as for the tree, if the ground is precipitous, from the tree slipping down hill. Hence it is best to make the tree fall more or less on a horizontal contour line, so that it may be at once caught up against the foot of the trees just below that line.

The trunk is liable to split along a considerable portion of its length if the tree falls before it is cut through. Hence a heavy tree, which originally bears down very much on the side on which it is to fall, should be held back or propped up until it is cut through, or a portion of its crown on that side should be removed. Moreover, no felling should be done in a high wind, which would, besides, prevent the woodmen from having any control in directing the fall of the tree in a given quarter.

The utilizable underground portion of a tree constitutes up to one-fourth the gross outturn of the portion above ground, and the amount of timber rendered useless or lost by felling the tree above ground may run up to from 6 to 10 per cent. of all the timber in the tree. To prevent this loss the trees should be felled by the roots, whenever the safety of the soil and surrounding vegetation and the nature of the soil and locality will permit, and the value of the wood thereby saved at least covers the extra expenditure it occasions. Even if there is no timber to be saved, this mode of felling is to be preferred, for, unless powerful machinery is available, there is no work so slow and arduous as grubbing out stumps—a mode of utilization that also yields a very large proportion of chips, which either have little value or are totally unsaleable. Neverthe-



less, when time is limited, it may be necessary to fell above ground and then extract the stumps at leisure.

The removal of the underground stock has, from a silvicultural point of view, the advantage that it thoroughly loosens the soil and thus favours the germination of seeds and the establishment and growth of seedlings. On the other hand, such loosening of the soil is dangerous on sloping ground or ground that is subject to inundation, while in sandy or otherwise dry and barren land it deprives the soil of so much manurial matter, and renders it too freely permeable to water.

If a large tree has to be exported in the log, it should not be allowed to fall or roll into a ravine or other hollow, from which its extraction would be impossible or extremely laborious and expensive.

To restrict, as much as possible, the damage to surrounding forest inevitable in all felling operations, the fall of every tree should be so directed that the tree may fall inside a gap between surrounding trees, or over a spot where there is least reproduction. In the midst of a close forest or abundant young growth the crown must be reduced, or may have to be altogether removed, particularly if the tree is very tall, as it is the portions farthest from the ground which acquire the greatest momentum, and therefore do most damage. In felling over dense very young growth, as in the case of after-fellings or in jardinage coupes, the seedlings should first be carefully bent away to either side, so as to form a narrow lane into which the tree may fall.

If, in spite of every precaution, a tree falls upon another so that its crown gets entangled in that of the latter and cannot be disengaged by merely trying to pull it away, then either a log or two must be cut off from the bottom, or, that expedient failing, one or more branches of the standing tree must be sacrificed.

As a rule, the amount of felled material lying on the coupe at any time should not exceed what may be cut up and removed within the next two or three days. Hence conversion should progress *pari passu* with the felling operations.

All large coupes should be divided into sections small enough to be worked by a single gang, and in each section the work must begin at one end and progress successively to the other end. On a slope the boundary lines between the sections should run straight up and down hill, and each section should run down the entire length of the slope, so that no gang may endanger another by felling above it. Small drainage basins or separate sides of a larger one constitute the most convenient sections. In each section

work must begin at the highest point, so that all the trees in the portions not yet operated in may aid in preventing the trees felled above them from slipping or rolling down. In clear fellings on level ground, as, for instance, in coppice coupes, the trees should be made to fall in the direction opposite to that in which the work is progressing, so that every portion of the area in which the fellings are still to be made may be quite clear of fallen material. Where a constant wind blows, the work should begin on the edge of each section and progress against the wind.

Trees may be felled either with some chopping instrument alone, or with the saw alone, or with a chopping tool and the saw combined. Stems cut back for coppice will not admit of the use of a saw, which would leave a spongy absorbent surface that would afterwards have to be smoothed with an axe or adze at great additional expense.

The different modes of felling will now be sketched in broad lines.

#### ARTICLE 1.—FELLING ABOVE GROUND.

##### (1). *Felling with chopping tools alone.*

Nothing special need be said here regarding the cutting down of saplings, except that when they are expected to coppice, their base should be supported with a stout piece of hard, knotty wood, in order to prevent the roots from being injured by the shock of the felling axe or bill.

In cutting back small poles, the fall of which, owing to their lightness, is easily directed, it is usually found convenient to cut all round the stem, thus giving the butt of the detached pole the form of an inverted cone.

In the case of larger stems, the fall of which it is important or absolutely necessary to direct, a horizontal cut should first be made on the side on which the tree should fall and extending to a little beyond half the diameter. This depth of cut is needed to prevent the bole, when the tree is beginning to fall, from splitting along the whole or some portion of its length—an accident of frequent occurrence with unskilful workmen. Another advantage gained is that if the tree is perfectly symmetrical, the vertical through its centre of gravity falls inside the cut, and the weight alone of the tree then bears it down on the side on which it has to fall. Even when the tree is over-developed on the opposite side, the deep cut helps it to be pushed or pulled over more easily in the required direction. The second cut should be made exactly

on the opposite side and almost meet the first. The operation is then completed by deepening this latter until the tree falls. The second cut may be made on the same level as the first one, so that the stump of the tree is given a perfectly horizontal section. This mode of cutting is indispensable in felling for coppice, in which case the stool is still further dressed into the form of a flat dome by sloping off the edge all round (*Fig. 49*). In all other

*Fig. 49.*

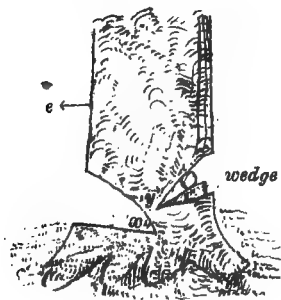


*Dome-shaped stool.*

cases there is very great advantage in beginning the second cut from 6 to 10 inches higher up, according to the size of the tree, as all risk of the bole splitting upwards is thereby avoided, and the tree is much more easily forced to lean over to the side on which it is desired to make

it fall. To still better secure this latter object, the second cut should be made slightly sloping downwards, as represented in the illustration below. Into such a cut wedges are easily driven in to force the tree to lean over to the opposite side. If the cut is wide, a billet of wood must be placed in it crosswise before the wedges can be inserted. The tree will fall only when the point *y* comes exactly over the point *x*, the fibres merely separating along *xy*.

*Fig. 50.*



*Mode of felling a large tree.*

In making any cut, the woodman should never, until it is complete, allow its two surfaces to meet at a sharp angle, as otherwise the natural tendency of the axe to work downwards, instead of parallel to the upper surface, will make his work very difficult each time he tries to widen the cut at the top.

Trees exceeding 18 inches in diameter are often best felled by several men together. Men working on opposite sides should cut with different hands, otherwise the cuts

will not be parallel, but form the letter *x*.

In making the two cuts necessary to fell a tree, a very large quantity of wood falls off in chips, while the wedge in which the butt-end of the felled tree terminates is of little or no use as timber. The quantity of wood thus lost is said by Boppe to be approximately as follows, according to the size of the tree :—

<i>Diameter at base, in inches.</i>	<i>Depth of cut, in inches.</i>	<i>Wastage, in cubic feet.</i>
12	10	0.5
16	12	1.4
20	14	2.5
24	16	4.2
28—32	18—20	6.4— 8.8
36—40	20—22	11.8—16.0

Felling with the axe alone is thus a very wasteful method, and should be confined to stems having a diameter at the base of not more than 12 inches. Where timber is very valuable, the maximum diameter may be reduced to even 6 inches. One great advantage of the axe is that with stems up to 12 inches or so in diameter it works much more expeditiously than any other hand tool.

(2). *Felling with the saw alone.*

The saw is made to cut continuously on one side (opposite to that on which the tree is to fall) until the stem is nearly cut through. To prevent the saw from jamming, as well as to gradually force the tree over, two or more strong wedges are driven into the cut behind the saw. To facilitate this operation, if necessary, the tree may be pushed or pulled over with the usual tools. As the single cut extends almost to the bark on the opposite side, unless the wedges are driven in skilfully, the tree is likely to fall in almost any direction within an angle of nearly 180°.

The amount of kerf is so small, that for all practical purposes there is absolutely no waste of wood with the saw. The saw should be used in felling all trees exceeding, according to the value of the timber, from 6 to 12 inches in diameter.

It is allowable to use the axe in order to round off buttresses and other irregularities.

(3). *Felling with the saw and axe combined.*

In this case a first cut is made with an axe on the side on which the tree is required to fall. This cut extends into the stem for only a fourth or fifth of its diameter, and its object is simply to make the work of the saw easier and to secure with certainty the fall of the stem in the exact direction desired. The saw-cut is made and opened out in the same way as when the saw alone is used.

## ARTICLE 2.—FELLING BY THE ROOTS.

All the main roots are laid bare with the help of picks, the smaller roots that come in the way being cut through with grubbing axes. The former are then severed with the axe or a curved saw, whichever is more convenient, those being cut last which anchor the tree on the side opposite to that on which it is to fall.

If the tree has no tap root or any other large roots penetrating into the ground more or less vertically, the procedure is very simple. All the main roots are laid completely bare up to the point at which they cease to have useful dimensions. In doing this, the secondary and other subordinate roots are cut through and removed with grubbing axes. The upper main roots, which are also the largest, are first severed close to the trunk with axes or a short curved saw, and then cut through at the further end and torn up with grubbing axes and wooden levers (poles of some hard, strong wood, from 6 to 10 feet long and cut into the form of a wedge at the thick end). The lower roots, on the contrary, are severed first where they are thinnest, as they are then more easily lifted up and broken off. The roots on the side opposite to that on which the tree is to fall should be cut last, and from the beginning the tree should, with the aid of a hook and chain or the thrust-pole, be forced gradually to lean over until the enormous leverage exercised by its crown brings it down, tearing asunder all the smaller roots that are still holding it. These roots cause the tree to fall slowly, and therefore with much less momentum, than if it were felled above ground, and hence, in this system of felling, there is less occasion for reducing the crown.

If the tree has a tap root or other roots running down more or less vertically, the upper roots are cut and removed as in the preceding case. When there is only a tap root, this should be cut into obliquely on two opposite sides, the cut on the side opposite to that on which the tree is to fall being deeper and the one by which the felling is completed. To help in deepening this cut as well as in bringing down the tree, a number of men should tug away at the tree in the direction in which it is to fall. By alternately pulling and giving, and causing the crown to sway forwards and backwards, greater effect is secured, and to prevent the trunk from swaying back too far, poles, thrust under it on that side, should be pushed in further and further as the tree bends forward more and more. In the case of several vertical roots, they must be cut through one by one, the most easily reached being attacked first, and the last being cut in the same manner as the single tap root.

When a screw-jack is available, trees with only large horizontal roots may be felled in the manner shown in *Fig. 45*.

#### ARTICLE 3.—GRUBBING OUT OF STUMPS.

The same procedure may be adopted here as in felling a tree, except that the enormous leverage of the crown and trunk is now entirely absent, and practically all the roots must be completely cut through. For the leverage of the upper portion of the tree must be substituted the action of the forest devil (*Fig. 43*), or of the stool-wrench (*Fig. 46*), or of the screw-jack (*Fig. 45*), or of windlasses, derricks, or winches.

Another way is to split and chip up the stump, converting it at once into firewood; but owing to the knottiness and crossing of fibres which characterise this portion of most trees, especially of broad-leaved species, this mode of extraction is generally extremely slow and can be adopted only very exceptionally.

Lastly, blasting powder or dynamite may be used. The blast-hole is made with a strong gimlet. It is best to bore it downwards through the centre of the stump; but in case of rotteness there, it should be bored sideways along a radius. In blasting with powder, the charge will be from 2 to 5 ounces, according to the size and nature of the stump, and the tamping should be done with clay or stiff loam. In the case of dynamite the charge will vary from 1 to 5 ounces, from 2 to 3 ounces sufficing, according to Gayer, for a stump from 20 to 28 inches in diameter. The stick of dynamite is put into the hole and rammed in tight with a wooden rod. Above this, in close contact, is placed the detonator containing the cap, to which the fuse is securely fixed. The rest of the blast hole is filled with clay or loam or fine sand. The fuse is fired with a burning piece of tinder placed in contact. When powder is used, the effect is often merely to rend the stool asunder, whereas the very much more powerful dynamite usually blows it up into numerous small fragments.

#### SECTION VI.—CONVERSION.

It will be most convenient to take up separately (1) the rough and ready conversion, such as can be effected by any gang of woodmen and which all felled material must undergo before it can be removed from the coupe, and (2) conversion into sawn goods. The manufacture of staves has already been described (pp. 57-58), and references have been made in various places to the preparation of felloes, sleepers, and some other classes of manufactured goods, which may be wrought in the forest.

## ARTICLE I.—ROUGH CONVERSION.

In every felling a certain amount of conversion is indispensable, primarily in order to reduce the produce to exportable dimensions, and secondarily to reduce the cost of export (for it is waste of money to carry out material that serves no purpose at all and has ultimately to be got rid of), and to render the produce readily saleable at the highest prices it can command. Hence the mode and extent of conversion in any case in question will depend on the purposes which the unmanufactured produce can be made to serve, on the demand and prevailing prices, and on the accessibility of the forest to the centres of consumption. The more valuable the timber is and the larger the demand for it, the more carefully and the more extensively must the felled material be converted. The question of conversion is, therefore, of the highest importance in the working of a forest, and requires on the part of the management an intimate knowledge of prevailing sylvicultural and economical conditions and frequently no little skill.

The procedure to follow in effecting rough conversion will be best stated in the form of briefly-worded rules, thus :—

I.—When practicable, the saw should be used, in order both to save material and to avoid, as much as possible, encumbering the soil with chips of wood. On steep ground, and where the trees lie all in a heap one over another, the use of the axe on a very large scale cannot be helped.

II.—The first thing to do, after a tree has been felled, is to trim off all branches and conspicuous projections. While this is being done, a number of men should work at the detached branches, the portions fit for timber being separated and trimmed like the trunk, and the rest cut and split up into firewood.

III.—Now cut up the trunk ; if necessary, removing from it what is fit only for fuel.

IV.—The timber portions should be kept as long as possible, in order to furnish the largest kinds of timber, while still being capable of being cut up into smaller goods. Division is necessary only when definite lengths of log are required (as when sleepers are to be sawn), or when the nature of the ground and communications place a bar on the export of logs above a certain size, or when the lower part has obviously a different utility from the upper.

V.—Timber must be presented to the purchaser in its most attractive aspect, and at least in such a form as will enable him to judge readily and with certainty of its quality and its suitability for his purpose. In round or roughly dressed timber, all burrs,

prominent knots, and other excrescences, &c., should be cut through and exposed; when straight pieces are required, all irregularities should be adzed off.

VI.—The bark may be removed by beating it with the back of an axe or with a special tool (*Fig. 51*), which is also useful when

Fig. 51.

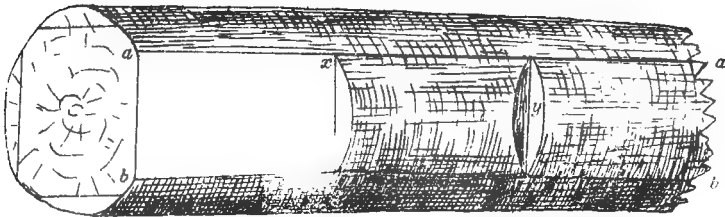


*Tools for stripping the bark off logs. (After Gayer).*

the bark has to be taken off only along certain lines, as described on page 23. The immediate removal of bark is a great protection against insects; but, on the other hand, in hot dry weather it leads to too rapid drying, and consequently to extensive splitting and cracking, unless the timber is worked up within a few weeks, or sometimes even days. Teak poles have, however, been known to remain free from insects throughout an entire rainy season if fully exposed to the rain, and then the dry bark has readily come off like a loose jacket, giving no chance to insects.

VII.—If the logs are to be carried over long distances by land before being sawn up, it will generally be found advantageous to rough-square them (convert them into balks). The procedure is as follows:—Having fixed the log firmly and in a convenient position for work and for obtaining from it the largest balk it can yield, the workman traces on the section at the thicker end, with the aid of a plummet and line and a carpenter's square, the lines of the four faces to be hewn (*Fig. 52*). Then, with a cord steeped

Fig. 52.



*Mode of rough-squaring logs.*

in water in which pounded charcoal or red hæmatite has been



mixed, he marks along the entire length of the log the lines *aa* and *bb*, which should follow as nearly as possible the outline of the log, and be as nearly parallel to one another as the taper and shape of the log will allow. This being done, he proceeds to hew with an axe the two vertical faces. But to enable him to work quickly and with accuracy, he begins by making at short intervals a number of guide cross-cuts *x, y, z.....*, the lines forming the bottom of which are vertical, so that all he has to do afterwards is to flitch off the portions between the cuts. It is always more convenient to stand upon the log while axing it, but not unfrequently our Indian wood-cutters stand on the ground next to the face which they are engaged in dressing. The remaining two faces are dressed in the same way, after changing the position of the log.

VIII.—Rough timber is adzed with the aid of the eye alone, the eight several faces, in order to diminish waste as much as possible, following closely the general outline of the log.

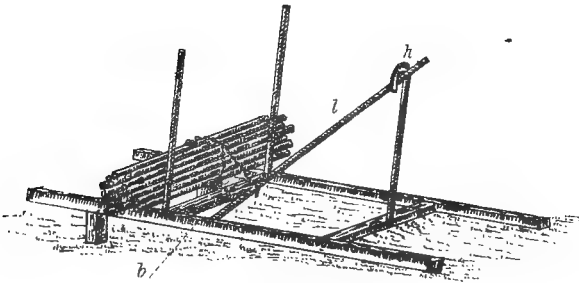
IX.—In preparing sided timber the workmen, after fixing the log firmly, must split it open along the vertical diameter of the lower section. The split must then be extended along the length of the log by constantly driving in a new wedge in front of the one last inserted and gradually forcing them home. No little skill is required to make the split follow more or less the same diametral plane from the beginning. The two halves are then dressed with the axe.

X.—Tors of heartwood alone are dressed with the axe. No guiding lines are traced, and the workman follows mainly the run of the heartwood, of which he endeavours to leave as much as possible, even at the sacrifice of straightness and regularity of shape, if the heartwood forms an irregular figure.

XI.—Firewood naturally divides itself into three broad classes, according as it consists of sections split from thick stuff or of unsplit billets or of small branchwood and the small stuff obtained by splitting up stumps and roots. These three classes should be separated at once as the tree is cut up. The rounds and thick billets from which the first class is obtained are taken off by sawing, and in India are usually from 2 to 3 feet long. The rounds are stood up on end, and a first split is made with axes driven in at two or three points along a diameter. When the split has been opened enough, before the axe is drawn out, wedges are inserted, 2, 3, or 4, according to the size and fissility of the round. These wedges are then driven home. It is advisable to have two men to each round, working opposite one another. If the halves thus obtained are too

large, they are further divided into quarters, and so on. Sometimes the billets to be split are too thin to stand up. In that case they must be laid lengthwise on the ground, with one end raised on a small billet, the splitting being begun at this end. The third class of firewood is too small to be conveniently moved without being tied up into bundles, whence the name of *faggot-wood* usually given to it. Small branches and branchlets are quickly formed into faggots by fixing four uprights firmly in the ground in pairs, the interval between the two pairs being equal to the diameter of the required faggot. The sticks are arranged between the pairs across one or more withies laid on the ground. When enough of sticks have been put on, the workman presses them down with one foot, while he binds up the withies. On taking his foot off, the expansive force of the pieces now released from pressure fixes firmly the twisted free ends of the withies. Perhaps a more convenient and time-saving apparatus is that shown in *Fig. 53*. The lever *l*,

Fig. 53.

*Faggot-binder's Press.*

the lower end of which rests up against the bar *b*, is drawn towards the operator and hitched into the hook *h*, thus tightening the chain over the bundle of sticks. The withy can now be tied up and the pressure on the faggot released by unhitching the lever. The length of the chain, which can be varied, regulates exactly the size of the faggot.

XII.—In the midst of abundant reproduction, as in seed and after-fellings and in jardinage coupes, and also in thinnings in a young forest, the less the amount of conversion effected on the coupe, the better for the safety of the standing stock. Hence all pieces that can be easily carried, such as poles, rounds, &c., should

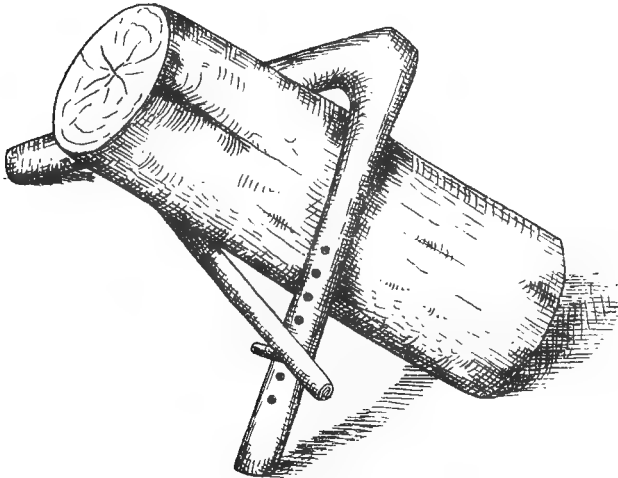
be taken out at once to the nearest roadside or large blank and cut up there. The same thing must be done in coppice coupes, when the time, before the new re-growth makes its appearance, is very limited. So also in the case of transport by water ; the pieces should be taken out as long as possible and cut up only on arrival at destination.

ARTICLE 2.—FURTHER CONVERSION OF TIMBER WITH THE SAW.

No reference will be made here to sawing by machinery, which is of too exceptional a character in India.

The first thing to do is to rough-square the logs in order to be able to fix them firmly enough for sawing. The amount of squaring required is of the very slightest, and may often be reduced to merely dressing one side flat enough to lie evenly on the trestles. When the contrivance represented in *Fig. 54* is used to support

Fig. 54.



*Delhi Sawyer's triangular trestle.*

the log, it will suffice to trim off only all prominent irregularities.

Next, the lines along which the saw must cut should be marked with a string in the same way as for rough-squaring. The section

of every scantling to be cut should be accurately traced on both ends of the log. The first set of lines at both ends should be drawn vertically with the aid of a plummet; the rest will, in nearly every case, run at right angles to these, and can then be ruled with the help of a carpenter's square. Before beginning any cut, the plane along which it is to run should be accurately indicated by joining the extremities of the corresponding lines traced at the two ends. In order to save time, as many such lines as possible should be marked off all at once. The slabs flitched off by the first cuts may often be thick enough to yield small scantlings.

The wood at the centre of a log is, as a rule, specially liable to decompose quickly and to warp and split. Hence this part should be removed if the sawn goods are to be used for any important purpose.

Speaking in a general manner, the saw-cuts may follow a radius or a tangent. In the first case, the entire width of the medullary rays, the *silver grain*, is made visible (whence the designation for this mode of sawing of "sawing with the silver grain"), and the layers of concentric growth run through the piece at right angles to the surface of section (*Fig. 55-A*). The medullary plates, being lustrous

Fig. 55.

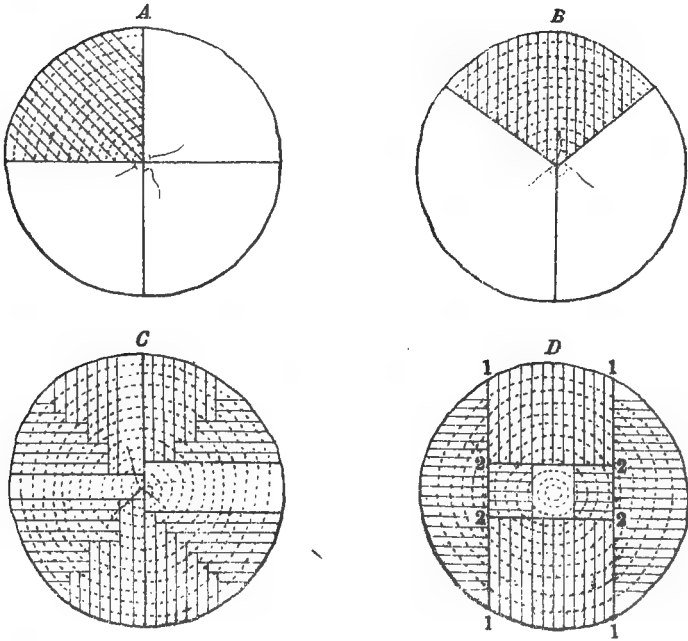


*Sawing (A) with, and (B) across, the Silver Grain.*

and harder than the wood fibres, contribute very greatly both to the beauty and lasting quality of the surface, while the uniform disposition of the concentric layers prevents, or at least minimises, any tendency to warp. On the other hand, a tangential section (*Fig. 55-B*) exposes principally the softer fibrous tissue, and the irregular distribution of the concentric layers exaggerates the tendency to warp in the direction of the concavity of these layers, and the medullary plates are invisible, except when they are extraordinarily thick, as in oaks. Actually the sections are seldom perfectly radial or tangential, but approach more or less one or the other of these two directions. For pieces in which beauty is a requisite, or for surfaces which, like floors, are subject to much wear and tear, sawing with the silver grain is essential.

*Fig. 56* exhibits several modes of sawing with the silver-grain.

**Fig. 56.**

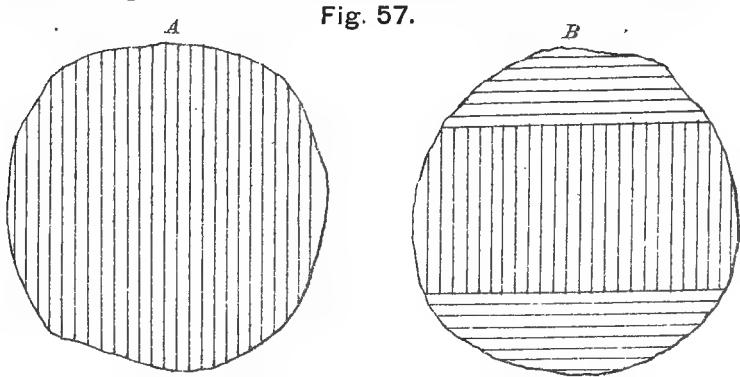


*Several methods of sawing with the Silver Grain.*

Methods *A* and *B* are practically the same, except that the latter gives more broad planks, although at a slight sacrifice of quality in respect of those taken from the outside of each section. In method *C* there is less waste of wood than in either *A* or *B*, and the pieces taken from the middle, where the silver grain is best exposed, can be of specially large dimensions. In each quadrant the planks can be taken off alternately one from each side, or alternately two and two, or three and three, or irregularly if the log is strongly elliptical. All three patterns, *A*, *B*, and *C*, possess this capital defect, that the widths of the planks cut are very different. This defect is, however, avoided in pattern *D*. In patterns *A* and *B* the wood of the centre of the logs, which is always of doubtful quality, is necessarily removed in squaring the inside edge of the planks. In patterns *C* and *D* the centre of the log has to be specially cut out. Besides that most of the methods of sawing with the silver grain yield planks of very various widths, the width of the widest planks is not even equal to the radius of the log. Hence, except for very special purposes, it is not usual to saw with the silver grain, and it

is preferable to adopt a mixed style of sawing, which will always give a certain proportion of goods showing the silver grain.

Two very frequently used methods of mixed sawing adopted for cutting out planks and boards are those represented in *Fig. 57, A* and *B*. *A* gives pieces of different widths, *B* pieces mostly of one



*Ordinary methods of mixed sawing.*

and the same width. The irregular edges of the planks taken off in *A* and from the side slabs in *B* can be sawn square with a single cut by placing several planks together one over another.

When pieces of different scantlings are in demand, it is best to obtain from each log as many of the highest-priced classes as possible. These should, therefore, be traced first of all on the ends of the logs, the remaining space being filled up as completely as possible with traces for inferior scantlings. In this way alone can the largest money-return be obtained from a given log and the wastage in sawing reduced to a minimum. Under the most favourable circumstances the wastage, resulting both from sawdust and from pieces that cannot be utilized, except as firewood, is never less than 22 per cent. if there is no objection to sapwood, or 33 per cent. if only heartwood is allowed. When only a single class of thick stuff is demanded, such as railway sleepers, the loss, even in cutting up perfectly sound logs, attains half the volume of the log.

When pit-saws are used, owing to their great length (8 feet), unless the logs themselves are long, these latter must be supported several feet off the ground across a pair of strong parallel trestles firmly fixed in the ground. With shorter saws it will suffice to raise only one end of the log by resting it on a single trestle, or, if the log is long enough, even across another log laid horizontally. The most convenient support for logs that are not too heavy is the triangular trestle so often used in the plains of Northern India

(*Fig. 54*). When only one end of the log is raised off the ground, the oblique position of the log makes the footing of the top-sawyer unsafe. To remedy this, a slab, one face of which is cut into teeth having the section of a right angle, is placed upon the sloping log with the smooth face downwards.

#### SECTION VII.—CLEARING THE COUPE.

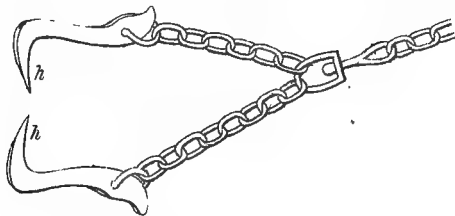
The produce may be removed either by rolling or dragging, or carrying on men's shoulders, or on wheels, or by sliding or sledging, or by letting it shoot down inclined ground or along a specially made channel. More than one of these methods may be employed together, and in choosing the method or methods to adopt, the objects to keep in view are economy and the safety of the forest and soil, as well as of the produce itself. The method to employ will also depend on the amount and price of labour available, the cost of cattle, and on the nature of the ground.

In clearing a coupe the different classes of produce must throughout be carefully kept separate, and it is always advisable to get the same gang to take out the produce, which cut and converted it.

Rolling can be adopted only on ground that bears no reproduction, and is at the same time fairly clear of trees, rocks, and other obstructions. If the ground slopes a little, so much the better. On steep ground logs can be rolled only in unfrequented localities, on account of the extreme danger to human life resulting. Rolling is a very easy mode of moving logs, being effected with ordinary poles cut to a wedge shape at the lower end, or, better still, with the lever and hook represented in *Fig. 47*. Trained elephants do the work very effectively and expeditiously on level ground.

Dragging may be effected either with human power or with draught cattle, according to the size of the piece or collection of pieces to be dragged. In the latter case a chain is fastened round the log and its ends attached to the yoke or traces, as the case may be. To save the trouble of fastening the chain to the log and then unfastening it, the contrivance shown in *Fig. 58* may be used, two

**Fig. 58.**



*Dragging Grappling-Hook. (After Gayer).*

holes being scooped in each side of the log to receive the end of the hooks *h, h*. The log is firmly held by the hooks in proportion to the tension of the draught. Simple levers have nearly always to be used to control the moving log or to lift the forward end off obstacles.

Pieces weighing up to 800 and even 1,000 pounds may be carried out on men's shoulders, if the lead is short.

Carts and barrows should be used only when the lead is long ; otherwise the labour and time spent in loading and unloading cease to make this mode of transport an economical one. Large logs are always much more cheaply dragged, especially if they are suspended, more or less by the middle, from the axle of a pair of high wheels. The hind end should slightly over-balance, but not to such an extent as to prevent one or two men from holding it off the ground, if necessary. If the axle-tree consists of wood, the ends may be made like a capstan head, to enable the log to be easily raised off the ground. The use of wheeled conveyance is of course limited to level even ground.

Only large logs may be taken out by sliding. On more or less level ground sliding is similar to dragging, except that the logs must be moved entirely on rollers. A simple device is to use two or three strong portable frames carrying well-turned rollers. As the log is slid off the hindmost frame, this latter is carried forward and placed in front of the advancing log. On slopes the logs may be pushed forward with levers. If the *dépôt* to which the logs have at once to be taken is some distance off, and the quantity of timber to be moved is large and concentrated within a limited area, a special sliding road may be made.

In this last case, if the pieces to be moved are small, a sledge road may be made instead of a slide, and a rough continuation of the road may be readily laid down (and as readily taken up) along successive lines of the coupe as the area is progressively cleared.

On very steep gradients the produce may be allowed to slide down of its own weight. No difficulty presents itself when the produce is to be collected at the bottom of the slope, except that the pieces *may* break and lose in value as timber. If the produce has to be arrested above the bottom of the valley, special works must be built up for the purpose. A channel or shoot, constructed of wood, may be used for the rapid transport of billets, for which class of produce this mode of moving is peculiarly well adapted.

#### SECTION VIII.—SEASONING AND STACKING IN THE FOREST.

Until the produce removed from the coupe is finally disposed of,



it must be stacked so as to season properly, without becoming full of cracks and shakes and without being exposed to decompose or be attacked by insects or fungi. In the case of pieces not more than a few inches thick, judicious packing prevents them from bending or warping, and helps to straighten those which are originally crooked.

In whatever way the wood is kept, the stacks or groups should be all of the same dimensions or contain the same number of pieces. There is no other way of keeping a correct and ready account of the produce.

### 1. *Seasoning and stacking of large unsawn timber.*

Such timber should of course be allowed to dry slowly and evenly. It should, therefore, be kept under shade if possible, but air should be allowed to play freely round each piece, especially if the season and the ground be damp. The pieces should hence be kept off the ground by skidding, unless they are to be removed again almost at once, in which case no stacking is necessary, the logs being simply placed together side by side in equal groups with the thicker ends all directed one way.

If the timber is to be kept for months, it should be carefully stacked as follows:—The lowest tier should be raised at least a foot off the ground and contain the largest and heaviest pieces, and there should be skidding of some inches under each one of the other tiers, the skidding being in every case perfectly level. The logs in each stack should have their butt ends all on one and the same side. Although free ventilation is necessary, a continuous current of air, especially of hot, dry air, should be kept out, and hence, where steady winds prevail, a screen of thatch should be erected on the windward side of each stack.

If it is necessary to take out a log here and a log there, it should be possible to do this without breaking up the stack. For this purpose, the smaller ends of all the logs should be kept slightly higher than the butts with small blocks of wood, and under the skidding over each tier should be packed similar blocks of wood from  $1\frac{1}{2}$  to 2 inches thick. By pushing away this packing, any log between two layers of skidding may be withdrawn without disturbing the remainder.

### 2. *Seasoning and stacking of sawn material.*

Thick stuff must always be put up in stacks without delay, in order to prevent them from drying too fast. When the pieces are

not broad, the tiers may be laid directly one over another, the lowest tier alone being skidded perfectly level off the ground. In this case, the pieces in two successive tiers will cross one another at right angles. An inch or two of space should be left between every two pieces in each tier. If individual pieces are likely to be required from time to time, it should be possible to take them out without breaking up the stack, and then small blocks should be placed under each piece; as soon as these blocks are pushed away, the piece which was resting on them can be at once drawn out. If the pieces are wide, each tier should be blocked below by laths from 1 to 3 inches thick and 3 to 4 inches broad. In every case, the last tier should be sheltered from sun, rain, and wind with a covering of thatch or inferior slabs of wood.

Thin deals, boards, and battens are extremely liable to warp strongly almost as soon as they have been sawn. They should be stacked without delay and kept as close together as possible until they are fairly dry, when they should be stacked like broad thick stuff. The last tier should be well weighted to prevent warping and sheltered in the usual way. Even if the timber is to be removed almost immediately, it should be stacked close together, as without the most careful and unremitting precautions a very large proportion of newly sawn stuff will be rendered useless or at least have its value considerably lessened by cracks and warping.

### 3. *Stacking and seasoning of poles and posts.*

While they are still green, poles should be piled up horizontally in stacks between pairs of vertical posts fixed firmly in the ground, and they should be well weighted on the top, in order to straighten those which are crooked and to prevent straight ones from becoming crooked in drying. If the stacks are not to be disturbed for some time, a few cross pieces should be laid under them on the ground as skidding.

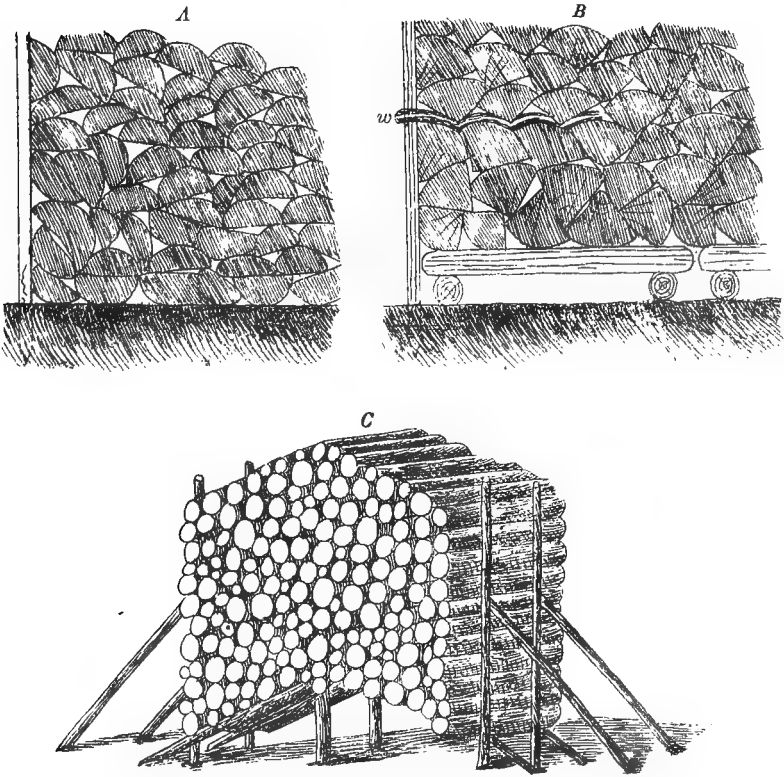
A common method adopted in many parts of India is to stand up the poles close together round the trunk of a tree, the thick end being on the ground. Placed thus, the poles are freely exposed to air and their upright position causes the sap to run down. Moreover, the crown of the supporting tree shelters the thin ends. Obviously only straight poles should be so stacked.

Posts may be stacked according to either of the two methods just described, but the second is preferable, as, even if they are crooked, they are not capable of being straightened under ordinary pressure, and straight ones cannot become appreciably crooked.

4. *Stacking of firewood.*

*Fig. 59* explains at once how to stack firewood. In *A* the pieces

**Fig. 59.**



*Methods of stacking firewood. (After Gayer).*

are in direct contact with the soil ; in *B* they rest on billets laid crosswise on the ground ; while in *C* the whole stack is completely raised off the ground and there is free play of air underneath. In every stack the pieces should be all of the same length and belong to the same category of firewood. The height of a stack should be uniform throughout, and should be such a figure that the height multiplied by the breadth should give a constant whole number—if possible, the number 10,—so that we have to measure only the length of a stack to know at once its contents. As the wood is bound to shrink considerably, causing the stack to settle down and its breadth to diminish, it is usual to allow the product to slightly exceed the

figure really required ; but in finding out contents it is always best to use this latter figure. On slopes a horizontal terrace is easily prepared for the site of a stack. To prevent the uprights, which support the stack, from being thrust away outwards, each of them may be strutted, or a strip of strong fibrous bark or a long withy may be put round each upright, as shown at *w* in *Fig. 58, B*, and kept in place by the weight of the wood lying on its united free ends. If necessary, two such ties or straps may be put round each upright. It is needless to say that the firewood pieces should be packed together as closely as possible.

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## CHAPTER IV.—DISPOSAL AND SALE OF WOOD IN THE FOREST.

THE question of supplying right-holders with the wood to which they are entitled belongs to the province of forest law, to which the student must refer for information. Here we shall concern ourselves only with wood to be disposed of by sale.

The conditions under which the sale of wood may be effected are infinite, and would require a large volume to be adequately dealt with. For our purpose it is necessary only to describe very briefly the most characteristic elementary systems of sale, a general acquaintance with which ought to suffice to form the judgment of the student. These systems are:—

- I.—The license or permit system.
- II.—The kham tahsil system.
- III.—The lease system.
- IV.—Sale of a small number of selected trees at a time.
- V.—Wholesale disposal of the trees of a coupe standing.
- VI.—Wholesale disposal of the trees on the coupe after they have fallen
- VII.—The forest depôt system.

### SECTION I.—THE LICENSE OR PERMIT SYSTEM.

In this system the would-be purchaser must, before he can enter the forest and begin to cut and collect his wood, purchase a license or permit, which, besides setting forth in detail the nature and the quantity of the produce he is authorized to remove, lays down certain conditions to be strictly observed, which have for their object the safety of the forest and easy and effective exercise of the necessary check over his action. For this purpose the permit must define the area within which he must cut, specify the road by which he must take out his produce, fix the period within which he must pass it out, and make it compulsory for him to submit his license and his goods to examination whenever called upon to do so by any competent Forest Officer. The license is usually in foil and counterfoil, the former being given to the purchaser, the latter being retained by the vendor for submission to the Accounts Office. Sometimes the foil is double, so that one part may be torn off by the person checking the produce when it first passes out of the forest, and sent independently of the counterfoil

to the Accounts Office to be compared with this latter. Besides this advantage of the double foil, the possession of only one part by a man inside the forest is proof positive of attempted fraud, as this part is meant only to enable him to pass on his produce to market or to his house, and to protect it as long as it remains with him. The check can of course be nearly as complete even when only a single foil is used, for the foil can be cancelled by means of some mark or endorsement as soon as the produce has left the forest ; but the double foil license is absolutely simpler to work, and in the present illiterate condition of the country folk and forest guards is also much more practical.

The amount of money paid for the license may be written on it, but illiterate purchasers are liable to be defrauded thereby, and in case of collusion between the vending and checking establishments, the forest revenue may suffer, as there is nothing easier than to enter different quantities and sums on foil and counterfoil, the counterfoil, in order to render detection more difficult, being written up only after the produce has been removed and the foil recovered and destroyed. It is, therefore, safest to indicate the value paid and received by means of colours and some readily recognized symbols impressed on the license or of adhesive labels resembling postage stamps affixed to it. In the case of different colours and symbols being employed, each license will possess an unchangeable value, whereas by means of adhesive labels it can be made to bear any value. This latter mode of denoting value is evidently much the better one. The stamps can be cancelled at once by the vendor, either in the same way as postage stamps, or by being punched through like court-fee stamps and railway tickets. Characteristic marks or letters can be similarly punched through at each check station or in each beat passed or traversed by the purchaser, thus denoting at once the route which he has followed and the extent to which he was under surveillance.

In the beginning of the system the vendors were also members of the checking establishment. In many places this is still the case ; but a great improvement effected in many others has been to authorize selected village headmen and patwaris to sell the licenses under the supervision of Forest Officers of and above the rank of Ranger, so that the people need never have to go far for a license, and the revenue is collected, as it should be, by men entirely distinct and removed from the protective establishment.

The license or permit system is an excellent one to adopt for small produce where the demand is comparatively light and there are no regular dealers and no near markets. The consumers being

generally too poor to pay the profits of middlemen, purchase their produce directly from the forest, and cut and remove it themselves at seasons when they and their cattle are free from labour in the fields. To prevent over-cutting, the forest should be divided into blocks, which are closed and opened in rotation. Under the strictest supervision a certain amount of damage to the forest is inevitable, and hence as soon as the demand becomes large enough to require and pay for more intensive management and to create a class of regular dealers, the system must be abandoned for one that gives greater control to the conservancy establishment over the exploitation of the forest. Nevertheless, until the trade in timber and firewood has obtained a very high development, it will generally be found advantageous to retain some form of the license system for the disposal of the very small wood which is of too low a value to bear long carriage. Two simple systems applicable in this case are those of tickets of fixed value, valid respectively only for the day of issue and for a month. The former leaves less room for fraud, but requires the establishment of vending stations on every line of export. Tickets valid for a whole month may be issued from a single central office. Such tickets are used with great success at Naini Tal, where they are made of brass, are consecutively numbered, and authorize the holder to remove head-loads of small firewood, of which, owing to the distance he has to travel, he cannot take out more than one a day. Infraction of the conditions under which the tickets are issued render the holder liable to forfeiture of his ticket, without prejudice to punishment under the law.

The license or permit system, in some form or other, prevails, as is to be expected, over more than half the forests of the empire.

## SECTION II.—THE KHAM TAHSIL SYSTEM.

In this system the would-be purchaser may enter the forest and cut and collect whatever he pleases within the authorised classes of produce, and he pays for what he carries away and obtains a pass for it only after he has taken it out of the forest and reaches a station where the money is levied and such pass issued. The system can of course be adopted only in forests from which there is a limited number of outlets. Such are forests situated in a mountainous country from which everything must pass out by the valleys, or forests lying behind a range of hills which are crossed by only a few passes, or remote forests for which the main highway to populous centres consists of one or a few large rivers. A very great disadvantage of this system, which is inseparable from the

mode in which the revenue is collected, is that it provides no check on wasteful or fraudulent cutting. Any one may fell more than he can or intends to take out, and dishonest people may cut without fear, in the hope of being able to smuggle out some part of the produce. The case is worst of all when the protective and revenue-collecting establishments conspire together with the smugglers. To minimise the chances of such collusion, the following precautions have to be taken :—(1). To establish two parallel lines of stations as far apart from one another as possible, the stations of the first line being on the edge of the forest. (2). On any consignment of produce reaching the first line, it should be counted or measured up and a pass issued thereon. (3). At the second line of stations, this pass and the produce should be checked together, and if no discrepancy be found, the pass should be taken away, the price of the produce collected, and a fresh pass issued. (4). Counterfoils, or in their stead a statement detailing their contents, should be despatched to the control office on the very day of issue. (5). Separate, responsible, well-paid inspecting officers should constantly patrol both lines of stations. If found more practical, the respective functions of the two parallel lines of stations can of course be reversed, the money being levied on the first line, and only a fresh pass issued at the second in lieu of the original pass issued on receipt of the royalty.

A very primitive form of the kham tahsil system is that in which the people who cut and bring the produce to the revenue stations are not purchasers at all, but act merely as wood-cutters and carriers. The purchasers themselves need not go nearer the forests than those stations. When the produce reaches such a station, the men who have brought it are paid for cutting, conversion, and carriage, and the purchaser, after paying royalty to the official in charge of the station, obtains a pass and takes away the produce under cover of it. This system has been adopted, as a matter of policy, in forests inhabited by poor aboriginal tribes, whose nearly sole means of subsistence is wood-cutting. It is also in force in some places for the working of bamboo forest.

Under the most favourable circumstances the kham tahsil system is a very clumsy one, and can have only a very limited application. Besides labouring under the essential drawback of requiring certain exceptional topographical features, it can, like the license system, be adopted for only the inferior classes of produce, and it is far more open to fraud than any other system. When the configuration of the country permits of its adoption, it may be resorted to temporarily, to encourage an incipient or languishing



export trade, especially if the forest population is a very poor one and dependent for its livelihood chiefly on the wood-cutter's craft.

### SECTION III.—THE LEASE SYSTEM.

In this system the lessee purchases the right to utilize and remove, during the term of the lease, as much of the specified classes of trees or produce as he has the time and ability to take out. Before any beginning was made in forest conservancy, certain forests were leased out for every article it produced, and even at the present day impecunious private proprietors, and indeed also rajahs, give out their forests on such terms. It is evident that a lease of this wholesale kind means the rapid extermination of the forest, and that the system itself is adapted only for the removal of inferior material from forests on which there is only an insignificant demand. Indeed, the lease system in any form is justifiable only when it is adopted to encourage the beginning of a trade in wood. Hence it is peculiarly suitable for clearing out of forests, that cannot otherwise be worked, the few trees that die and fall naturally every year. In the case of a large accumulation of dead material, the system would be justified only in the absence of a keen competition to obtain this material. Under any other circumstances the lessee would always be tempted to try to pass off green for dead wood, and, if he could afford to wait, to kill a number of valuable living trees, which he would extract after they were dead. As the number of trees that die each year from natural causes is, under normal conditions, comparatively insignificant, the forest should be divided into blocks, each block being leased in turn only at the end of a period long enough to allow of a sufficient accumulation of dead wood to attract purchasers and thus command remunerative prices.

The forests of the Saharanpur Division of the School Circle, containing, as they do, a very inferior stock, are a good illustration of the successful application of the lease system, but the interval during which each block has rest would perhaps with advantage be extended.

The weakest point in the lease system is that, as the lessee pays down a fixed lump sum, it is his interest to remove as much produce as he can, and he is, therefore, under constant strong temptation to take out also what he has no title to. The lease system is totally unsuited for the working of bamboo forest, as no amount of precaution will prevent over-cutting in individual clumps.

The lease money may be recovered in one instalment before the

lessee is allowed to begin operations or recovered in two or more instalments, the first to be paid down immediately on conclusion of the sale, the last while there is still enough produce in the forest to cover the balance due. In the case of petty sales it is best to exact a single instalment paid in advance.

#### SECTION IV.—SALE OF A SMALL NUMBER OF SELECTED TREES AT A TIME.

Under this system a small number of trees are given on special application, the applicants being generally the would-be consumers themselves or petty tradesmen. This is the mode of sale to adopt when the demand is insignificant and irregular and is limited to large and valuable timber. It is specially well adapted for the sale of the larger and more valuable trees standing in areas which are worked for the less valuable portion of the material by the license or the kham tahsil system. It may also be employed for the disposal of the best trees in regular coupes; but in this case there is always risk of the value of the remaining produce being depreciated out of proportion, owing to the previous removal of the best material, and in some cases the depreciated stock may even fail to find a purchaser.

The trees selected for removal may of course include dead and naturally fallen trees as well as those standing. Standing trees should be marked at the foot only if they are to be converted before removal, and at the foot and also just above the place where they are to be cut off, if the trunk is to be taken out round. When the produce is converted before export, each piece should be stamped with the sale mark before it is allowed to be removed. The sale mark should also be similarly put on round logs before they are taken out.

#### SECTION V.—WHOLESALE DISPOSAL OF THE TREES OF A COUPE STANDING.

This system cannot obviously be adopted for the produce of cleanings and early thinnings, in which operations the felling has to be effected by the owner's agency. Its employment is also out of the question in the absence of a large class of well-to-do and honest dealers. When it can be adopted, it is by far the best method to employ, as it leaves the conservancy establishment completely free to devote itself to its legitimate duties of culture and protection.

The trees being marked for sale (or girdled and killed, as in Burmah), the first point to decide is whether they should be sold by public auction or by inviting sealed or open tenders; also

whether their sale price should be recovered as a lump sum covering the entire lot or at so much a tree, according to species and size, or at so much per unit or number or volume of converted material.

When purchasers, eager to buy, readily offer themselves, the system of sealed tenders is the best, as public bidding at an auction and open tendering enable the dealers to combine. In the State forests of France the following mode of public auction, termed *vente au rabais*, is, however, said to prevent such combinations. A short candle, capable of burning about 5 minutes, is lighted and the auction is declared open. The crier begins by calling out a sum considerably in excess of that at which the Forest Officer has estimated the value of the coupe, and at regular intervals he goes on diminishing this sum by a small fixed amount. The auction lasts only as long as the candle is burning, and the sale is adjudged, at the figure last called, to the first person who cries out "I take." Each bidder, knowing that the time is limited to only a few minutes, is usually only too eager, as soon as a figure is reached which he thinks will yield him a profit, to cry out "I take," being afraid of being forestalled by another. This method of sale is practicable only when the bidders are quick-witted men of business, and is unfortunately not adapted to the haggling spirit engendered by the Indian mode of buying and selling.

In the case of sale by sealed tenders a certain date is fixed by which all such tenders must be sent in. On a day and at an hour notified beforehand, the tenders are opened in the presence of any of the tenderers who wish to attend, and the terms of the tenders are read aloud, so that the proceedings may be entirely of a public character and above suspicion. To prevent people from making tenders which they are unable to carry out, every tender, before it can be received, should be accompanied with a deposit of money, which is forfeited in case of non-fulfilment of the tender. The adoption of the system of sealed tenders is impossible without the existence of a sufficiently large class of enlightened and enterprising dealers, as the excitement that naturally accompanies the public bidding at an auction and incites to keen competition is entirely wanting in it. It is totally unsuited to men who have not risen above the haggling spirit of the Indian buyer and seller. But when the proper class of dealers is not wanting, it is the best system to adopt, as it saves time and worry, and effectually prevents combination, since every tenderer, being anxious to secure the sale for himself, and not knowing what the terms tendered by other people are, offers as high a figure as he, according to his lights, thinks will yield him a sufficient and legitimate profit.

In the method of open tenders would-be purchasers may apply, either personally or by letter, and at any time within a given date, but the Forest Officer is not precluded from foreclosing with any tenderer before the expiry of that date. In this method of open tender an opportunity is afforded of bargaining, which must be made the most of. The terms offered by the various tendering parties may be disclosed or not, according to the discretion of the vendor. The system is, however, liable to induce combination amongst dealers, as the vendor is obliged more or less to disclose his hand to the first tenderer; moreover, unless the value of the produce in question is well-known and is not subject to wide fluctuations, the vendor is exposed to commit himself to prices which subsequent tenders may prove to be too low, and in such case the system of sealed tenders or of public auction is preferable.

Whether the value of the produce sold should be fixed as a lump sum for the whole lot or recovered at so much a tree, or at so much per unit or cubic foot of converted material, depends principally on the condition of the market and the nature and character of the purchaser. If the purchaser is honest and understands his business thoroughly, it is best to sell the whole coupe for a lump sum, thus obviating the heavy tedium and labour of classifying and counting all the produce, of keeping a complete voluminous register of it, and of making endless calculations in order to ascertain the price of each one of the numerous classes of which it consists. The benefit accruing therefrom to the purchaser is equally great, since it relieves him at once from the thousand and one obstructions and petty annoyances to which he would otherwise be liable from the people checking his operations. But in the absence of a sufficiently honest and enlightened class of dealers, it is impossible for the Forest Officer, who necessarily has little acquaintance with the market, to know whether the lump sum offered represents anything like the true value of the coupe or not. In that case it is safer for him to receive the value of the produce according to the quantity of each class of material taken out of the coupe, and it remains for him to decide whether the unit of sale shall be a tree or a cubic foot or the number of pieces of each class. Of these three bases of valuation, the first is the simplest, as the total value of the coupe can then be at once calculated, and this amount can be treated as a lump sum due from the purchaser, thereby avoiding all chance of future disputes. But this system is not applicable in a forest in which the quality of the trees varies very much from place to place. For instance, large profits for a few years, owing to the trees sold having been sound and well-shaped, may tempt purchasers to give unusually

high prices at subsequent sales ; but the trees proving unsound, heavy losses are incurred. The confidence of dealers is thus once for all shaken, and in future, however good the trees may be, the rates offered are based on the assumption that the trees are no better than the worst descriptions obtained before.

Hence, when the quality of the trees is very variable, it is best to charge the purchaser rates based on unit of volume or number of pieces of converted material. When volume forms the basis, a considerable amount of labour is inevitable in working out the total sale-value, if the number of pieces to be measured is large. Moreover, very few of our Indian purchasers are familiar with the methods of timber measurement. Hence, except for large logs, the contents of which obviously differ very much one from another, it is best to fix the rates on the basis of number units, which can be understood by the most illiterate purchaser. The unit rates on which the value of the produce is calculated must of course be originally fixed by measure of volume. The use of the numerous published tables of timber measurement will aid very materially in lightening the work of calculation in either case.

In some places, the better class of timber dealers care to utilize only the best logs and to take out only timber of the highest quality. Such purchasers will either leave the inferior timber untouched, or, as they look only for large profits, will take it out only at disproportionately low rates. In such cases it is best to admit into the coupe two or more separate purchasers following each other, the first taking out only the finest timber, the second the next best class, and so on until every saleable stick has been removed. This method has been followed for many years in the forests of the Central Circle of the N.-W. Provinces and Oudh with the best results. It is peculiarly suitable for India, where the small dealers are men who are satisfied with profits giving them an average income of a few rupees a month ; but it necessitates keeping even the smallest coupe open for exploitation for at least a couple of years, as it would be impolitic to let in a new purchaser until the previous one had cleared out all his produce. But even when the owner of the forest sells the whole produce of the coupe to a single purchaser, it will often happen that this latter will himself remove only the best timber and admit petty tradesmen and consumers to take out the rest at prices which he will constantly lower as the better class of the remaining material is taken away or the distance or difficulty of transport increases.

When the value of the coupe is estimated in a lump sum, this amount should be recovered in not less than two instalments, the

first one being taken before the purchaser is allowed to begin work, and the last while there is still enough material (whether it be scattered over the whole area or collected at temporary depôts) to cover the amount of the instalment. In the event of any instalment not being paid when it falls due, there should be a proviso in the written conditions of sale to empower the owner to recover it by seizing and appropriating the produce remaining unexported. If the value to be paid by the purchaser is calculated on the basis of unit rates, the money may be recovered in the same way, or in one of two other ways. Either the purchaser may be made to pay down a sufficiently large sum as earnest-money on the conclusion of the sale, and to make good the balance when all the produce has been collected and counted or measured up, as the case may be, or he may be required to pay the value of the produce as he takes it out, the earnest-money in this case being refunded to him when his operations have been completed. What is termed the "permit and revenue depôt system" and adopted in the Central Circle of the N.-W. Provinces and Oudh, is a practical application of the latter method. The system in question is a development of the kham tahsil system, which it can replace at once without any derangement of current arrangements, the revenue stations serving at once as depôts where the out-going produce has to be stopped for check and counting or measurement and the price has to be collected, and the only change required being that instead of any and every one being allowed to go into the forest and cut and collect what he likes, only *bonâ fide* purchasers, with whom distinct contracts have been made, may cut and export. It is always impolitic to put temptation in the way of people on small salaries, and hence, where Government treasuries or private banks are not far off, the large sums of money due at various times from the purchaser of whole coupes should be paid direct to a treasury or bank, the pass for the wood being given to the purchaser on his presentation of the receipt for the money. And, whenever possible, only well-paid officers, holding high responsibility, should be authorized to measure up and value large quantities of produce, which are to be paid for on the basis of unit of volume or number.

#### SECTION VI.—WHOLESALE DISPOSAL OF THE TREES ON THE COUPE AFTER THEY HAVE BEEN FELLED.

In this case the owner fells the trees and then sells them, as they lie on the ground, to one or a series of wholesale purchasers, as the case may be. The object of felling the wood himself is to ensure

that every stem whose removal is necessary for the improvement of the forest is got rid of, since, in the system just described above, the very crooked trees and those of inferior species may be left standing by the purchasers as not being sufficiently valuable to give them the profits they require. In all other respects, however, the procedure to follow in the present system does not differ from what has been described under the preceding one.

The felling of the trees by the owner also secures another important cultural advantage. It enables him, in young forest or where there is a mixture of ages, to cut back all badly grown saplings and small poles the re-growth from which would very appreciably improve the constitution and future of the stock. Such saplings and small poles having little or no value, the purchaser of standing produce might not have sufficient inducement to cut them back, even if the price he had to pay for the coupe was considerably diminished on that account. Hence in all cleanings and early thinnings, in nearly all improvement fellings, and often in after-fellings and jardinage coupes, this system must necessarily be employed, and in the two last classes of fellings, even if the system is not adopted for the entire cut, it must be followed in the minor operations which, forming an essential part of the felling, have for their object the improved growth of the younger generation.

As in this method of sale the coupe gets littered with small and very inferior produce, the principle on which it is based can be adopted only where there is a demand for almost every portion of the cut. The system cannot be applied to the sale of trees that are scattered over a large area, as the cost of felling them would eat too much into profits. It is for this reason that in the Dehra Dûn sâl forests only the trees which are above 6 inches in diameter are sold standing, the inferior stems, the removal of which is doubtful, being girdled to make sure of their disappearance.

#### SECTION VII.—THE FOREST DEPÔT SYSTEM.

In this system the owner not only fells all the trees, but also subjects them to a certain amount of conversion and collects them into smaller or larger lots on the nearest roadside or in neighbouring blanks, from which their export can then be effected with ease and without injury to the forest. This system is adopted when purchasers cannot be trusted to work inside the forest without hurting or plundering it, or when the management has plenty of time on its hands, labour is easily obtained and organized, and the owner is anxious to secure for himself a part of the profits that would otherwise fall to the purchaser.

The collected produce may be disposed of wholesale to a single purchaser or in assorted lots to several purchasers or in a more or less retail manner, and the sale may be effected either by auction or by sealed or open tenders, or according to a published tariff.

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## CHAPTER V.—MANAGEMENT OF WOOD DEPOTS AND TIMBER YARDS.

IN the chapter just completed the sale of wood in the forest was described. In the present case, the wood, after undergoing a considerable amount of conversion, is brought to a depôt within convenient reach of the market. A depôt of this kind is, therefore, necessarily of a permanent character, and is maintained on a very much larger scale than mere forest depôts. It requires the entertainment of a special resident establishment, which can be more fully utilized and better paid the larger the depôt is, thus securing at once economy and honesty.

The most important points to attend to in such a depôt are a correct classification of the produce in accordance with the market demand, and such an arrangement of the different classes that they may be found at once and every piece examined without any trouble. For facility both of check and of sale, the pieces in each class should be put up in stacks or lots of definite size or containing a definite number of pieces. Provision should also be made for the easy removal of every piece of wood. For this purpose the entire area should be divided off into compartments containing each a main class of produce, and each compartment into sub-compartments destined to contain separately the various categories of each class. The division lines may be roads fit for carts or laid with rails, according to the amount of traffic.

Very large logs, too heavy to be moved without great difficulty, should all be kept only in a single tier with the butt-end facing the road. Smaller timber should be stacked in the way already described on page 115.

In very large depôts, sheds may be built to shelter the more valuable goods and to allow them to season properly. In these sheds, in order to economise space, the ceiling should consist of strong, open wood or iron work, capable of bearing boards and smaller sawn material. While a perfectly free circulation of air throughout the shed is necessary, draughts, especially of very dry and hot or very damp or cold air, should be prevented, and the temperature inside kept as equable as possible.

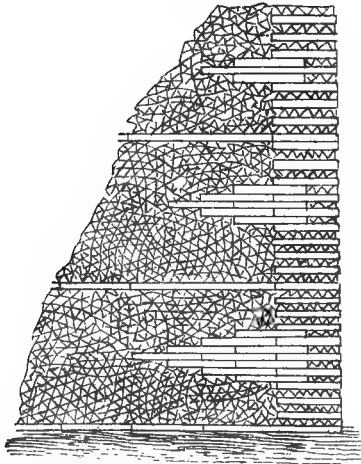
A further precaution for timber that is not yet completely seasoned is to plaster the ends with a mixture of clay and cowdung. It

is surfaces exposing a cross-section that give out moisture most rapidly and are most liable to form cracks, and the object of the plastering is to diminish the rapidity of evaporation. Wood intended for carving or engraving should be kept in short lengths, round pieces being sawn along their entire length down to the centre, so that as the various concentric rings of growth contract, the saw-cut opens out wider and wider, without a single important crack occurring.

Sometimes it may be necessary to water-season timber (see page 20). In that case there ought to be a large or several large tanks, and until the pieces thrown in sink of themselves or unless they are forcibly kept under water, they should be constantly turned, otherwise decomposition would soon result in the portion near the water line.

The smallest stacks of firewood should have a square horizontal section, the side of the square being equal to the length of the billets, and the height such a figure as will bring up the contents of the stack to 10 cubic feet, or a little more if allowance is to be made for shrinkage. Larger stacks may be built up like those described on page 117, and should contain some multiple of 10 cubic feet. For wholesale dealers, specially large stacks, having a square horizontal section of 10, 20, 30, 40, and even 50 feet side, should be built up. No little skill is required to give them sufficient stability. *Fig. 60*

Fig. 60.

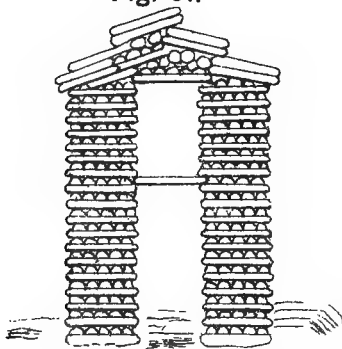


*Mode of building up large stacks. (After Gayer).*

shows a very good plan to follow. In it the corners are tied very

ingeniously, and, in order to secure uniform shrinkage, horizontal rows of straight pieces should be laid at short intervals, thus building up the stack in regular layers. Occasional long pieces should be inserted with the same object with which headers are employed in masonry. In the case of firewood that has been floated, there should be no delay at all in spreading the pieces out to dry, and stacking them so that they may be freely exposed on every side. In *Fig. 61* is exhibited a very successful mode of building such stacks.

Fig. 61.



*Stacking moist wood. (After Gayer).*

It is hardly necessary to say that every precaution should be taken against the occurrence of fire, and for this reason the site of the depôt should be specially selected for its proximity to an abundant supply of water. As it is easier to suppress a fire that is just beginning than to attack one that has already spread, numerous pots of water should always be kept handy at different points.

Besides depôt registers punctiliously written up as each transaction occurs, a special rate-book should be kept wherein all fluctuations of prices both at the depôt and in the open market are carefully recorded.

The mode of sale will generally be by open tenders, sealed tenders and public auctions being resorted to only in the case of such stock as must be got rid of at once. Stock of this kind will generally consist of deteriorating material or material likely to deteriorate if not sold off quickly. But if it is not possible to place a well-paid and trustworthy man in charge, the only plan to follow in effecting the ordinary sales is to fix from time to time, for the guidance of the establishment, a tariff of prices, to which the utmost publicity should be given.

At all large depôts the establishment of saw machinery will never fail to result in a marked increase of revenue. By its means the scantlings most in demand could be prepared at once, either on indent or in expectation of buyers, and all odds and ends could be utilized to the utmost extent of their value. For this reason, it would be an advantage to place the depôt where water-power can be used, since such power costs next to nothing, and the machinery required for it is of the very simplest description, being most of it capable of being repaired without skilled labour. In the absence of such advantages, steam machinery must be used, the wood refuse supplying the necessary fuel. In Government depôts no wood-working machinery beyond a simple saw bench should be introduced, further conversion being properly left to private dealers.

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## PART II.

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### COLLECTION, PREPARATION, AND DISPOSAL OF MINOR PRODUCE.

UNDER the term minor produce is included every useful substance that can be obtained from a forest besides timber and firewood. The forests of India are particularly rich in minor produce, both in regard to quantity and variety, and a knowledge of how to utilize the various descriptions of such produce is, therefore, of peculiar importance to us. At present, owing to the backward condition of the country, the demand is limited; but with the development of means of communication, a rise in the standard of living, and the continued expansion of internal as well as external trade, the exploitation of minor produce will become a most important source of national wealth.

A complete study of the utilization of every article of minor produce would lead us a great deal too far, and would require several large volumes. Here it will suffice to consider in a general manner how they are obtained from the forest, and to what extent they may be utilized without unduly interfering with the main end of silviculture, namely, the production of timber and firewood. The subject will be treated under nine principal heads as follows:—

- I.—Utilization of herbaceous vegetation.
- II.—Utilization of the flowers and fruit of trees and shrubs.
- III.—Utilization of the bark of trees and shrubs.
- IV.—Utilization of the leaves of trees and shrubs.
- V.—Utilization of minor produce obtained from wood and from the interior of stems.
- VI.—Utilization of minor produce furnished by the roots of trees and shrubs.
- VII.—Utilization of exuded products.
- VIII.—Utilization of animal products.
- IX.—Utilization of minerals and some other products.

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#### CHAPTER I.—UTILIZATION OF HERBACEOUS VEGETATION.

The herbaceous vegetation covering the ground in our forests is peculiarly abundant, but consists chiefly of grass. On it, at pre-

sent, depends the entire system of agriculture of the country, and hence its title to first consideration. It supplies (1) pasturage, (2) hay and cut green-fodder, (3) ensilage, (4) litter, (5) fibres, (6) material for thatching and for making mats and baskets, and (7) drugs, dyes, &c.

### SECTION I.—PASTURAGE.

In the present condition of our agriculture, pasturage is the most important want supplied by the herbaceous vegetation growing in our forests. Nearly half the live-stock of the country depends entirely on the forests for its sustenance, while an extremely large proportion of the rest is driven for some period or other of the year to graze there. Forest grazing has been for so many ages an essential part of our rural economy, that with a climate opposed to meadow cultivation on any appreciable scale, and national habits and religious prejudices which preclude any extensive consumption of meat, it will always continue to be the chief mode of feeding cattle.

The fields, owing to the enormous population and to India being one of the granaries of the world, will never cease to be used principally for the production of food-grains, oil-seeds, and fibres, fodder being, as now, only a by-product. Thus we must submit to most of our forests being used as permanent pasture grounds, and must accordingly arrange for the fullest utilization of the fodder they yield, consistently with the production of timber and firewood. The forest-grazing question acquires its highest importance in dry countries with a low rainfall, and in hilly and mountainous districts where the extent of available arable land is usually hardly sufficient for producing the food of the population.

The advantages accruing to agriculture from forest-grazing are thus unquestionable and incalculable. For the forests themselves, the advantages are few and only occasional, while the disadvantages are enormous, and may tend to the extermination itself of the forest.

The advantages may be said to be four in number. Firstly, grazing helps to keep down the rank growth of grass and weeds, which come up in profusion even under a dense leaf-canopy with only a modicum of light, and interfere with reproduction. Secondly, when the ground is sloping, but not so steep as to require careful protection against slipping, the going to and fro of cattle breaks up and loosens the surface soil and thus prepares it for reproduction. Thirdly, where in open glades and blanks the soil gets

covered with a close matting of grass roots impenetrable to the delicate roots of forest seedlings, there the sharp feet of cattle and the plucking action of their bite combine to tear up the grass at numerous points and thus make openings for seedlings. Lastly, in all conifer forests, without the crushing action of the feet of cattle, the dry undecomposed needles form a thick layer over the ground, through which the roots of seedlings are unable to reach the mineral soil below, or are at least able to do so with difficulty.

Exceptionally, a fifth advantage may be derived from regulated grazing. In mature babul forest, when a new generation of seedlings is required, the appearance of this latter is singularly accelerated by admitting goats and folding them at night within the area while the pods are falling. The seeds that have been voided by the animals germinate without delay, whereas the rest generally take at least a whole year to sprout, during which time they are exposed to every cause of injury or even complete destruction.

The principal dangers arising from grazing are as follow :—(1). The removal of the herbaceous vegetation means the loss of so much manurial matter, including potash, phosphorus, and nitrogen in its most assimilable form. (2). The animals break and crush young seedlings, the heavier kinds under their broad hoofs, sheep and goats with their sharp and quick-moving feet which cover but little ground at each step, the mischief being aggravated in the case of sheep by their moving in a dense mass together. (3). Forest-bred cattle, and even those that are only partly stall-fed, acquire the habit of eating the leaves and twigs of forest trees with as much relish as they browse off grass and herbaceous vegetation. All cattle without exception, when very hungry, fall greedily and indiscriminately on every green thing before them ; and we know in what a starving condition the animals are brought into the forest every year from the villages. To make matters worse, these animals arrive when the grass is dry, hard, and tasteless, so that in their famished condition they make at once for all the low forest growth, which, as-a rule, puts forth new foliage before the new grass makes its appearance. Now we know that a woody plant suffers most and recovers least easily while its new flush of leaves is coming out. Thus the heaviest grazing occurs during the most dangerous season for forest vegetation. Broad-leaved species, yielding, as they do, the best fodder, suffer most. (4). When the soil is wet, the constant tread of the animals beats it down into a hard pan quite impenetrable to the roots of forest seedlings, and it is when the soil has been drenched by rain that seeds germinate ; hence the presence

of cattle during the rains, and, in the Himalayas, also during spring, is a great bar to natural reproduction, if it does not entirely prevent it. (5). Young animals are much more destructive than old ones, since they nibble at forest growth not only for their food, but also sometimes from pure mischief ; sometimes to relieve the irritation arising from the cutting of new teeth. (6). The continued admission of goats into a forest results, in a few years, in its complete disappearance, since these animals prefer the leaves of woody species, when they can get them, to the finest grass. They also gnaw off bark, and, besides standing up to their food, they throw themselves on to flexible stems, thus bending them down under themselves and getting at the tops of saplings up to 9 and 10 feet high. Even camels, in spite of their very much higher reach and the peculiar way they have of tearing off a long succession of leaves and twigs, are less to be dreaded than goats. Sheep, from naturally holding their heads along the ground, will seldom touch anything else if they can get grass ; but when the grass is dry and hard, they may nibble off leaves at the height of their heads. Buffaloes, even when they eat only grass, crush young growth up to the size of saplings, and when hard pressed for green food, have been known to use their enormous weight to bend down to the ground poles up to 12 inches in girth and 14 feet high. Cows are the least harmful of all domestic stock (elephants, ponies, and horses are in too small numbers to be taken into account), and will, as a rule, not touch seedlings and saplings of forest trees, even if abundant and mixed up with the grass, unless this last is very bad indeed.

Some species, such as *Anogeissus pendula* and *Prosopis spicigera*, are extremely resisting to the effects of constant browsing ; but, even in their case, the appearance of new seedling growth, except in the midst of thorny bushes, is an impossibility, and the individuals that survive are permanently stunted and often reduced to low twiggy knotty bushes which spread out along the ground.

The advantages and dangers connected with grazing in the forest have now been briefly considered. It has also been shown that the provision of grazing on a large scale is, in present circumstances, an unfortunate necessity. Some general rules must hence be given for regulating its exercise, while avoiding or minimising the attendant risks. In the first place, goats and camels must be rigidly excluded from all areas which are intended to grow wood, mature babul crops being, however, excepted in favour of goats during the fall of seed immediately preceding the required appearance of the new crop. All other animals also must be excluded from areas under regeneration or containing abundant



young growth not above their reach, while the ground is soft and sodden or seeds are germinating or the grass is dry and wiry and the tree-species are in leaf or coming out into leaf. Otherwise cows, buffaloes, and in many cases even sheep, may be admitted in restricted numbers and in small herds or flocks at each place, since a number of animals moving in a mass would make a clean sweep of everything before them and tread the soil into a hard pan. In regulating the size of the flocks and herds and apportioning to them the areas in which they may range, we may assume that for every 100 lbs. of live weight each animal requires per diem from 10 to 12 lbs. green weight of fodder, and that an acre of forest land, inclusive of unproductive portions and fully canopied areas, produces, on an average, about 12,000 lbs. green weight of edible grass, of which hardly one-third remains in a fit condition to be eaten during the six months of the year that grazing is permissible. It is, therefore, evident that the smallest area of forest land that can be assigned per head for those six months cannot be less than  $2\frac{1}{2}$  acres for cows, 4 acres for buffaloes, and  $\frac{1}{2}$  acre for sheep. These are minima figures, and the actual areas assignable, after deductions in the interests of reproduction, unstable soil, &c., will considerably exceed those figures. If more cattle are admitted than the forest can stand, we must make up our minds to sacrifice the woody growth: excessive grazing and forest growth are totally incompatible terms. Actually, in many places, the number of head of cattle is in excess of the capabilities of the forests, and the assumed necessity (in nearly every case totally unfounded) of providing grazing for the entire number is the cause of so much lamentable deterioration and arrested progress visible everywhere. It is undeniable that the number of cattle is enormously in excess of requirements. At any rate, hundreds of thousands of utterly useless brutes ravage the forests, and two half-starved, ill-bred animals have to be used where a single well-fed, well-bred one would suffice. Thus, were it not for the neglect and apathy of the Indian agriculturist, the demand made on our forests for grazing would probably be well within the capability of nearly every one of them. To overcome this neglect and apathy of ages we must enlist on our side the sympathies and powerful aid of the Agricultural Department.

Each group of animals must be in charge of responsible herdsmen sufficiently numerous to control them and to drive them over the entire allotted area, so that no part may be overgrazed. In areas into which cattle are admitted to keep down the grass and weeds, or to wound the soil or to crush an excessively thick layer of dead

undecomposed débris, it should be a condition of admission that they are driven regularly backwards and forwards over the whole area, and especially there where they can do most good. If the animals are penned within the forest at night, a special spot must be fixed for them which is a natural blank, and is not immediately surrounded by promising and abundant young growth. Every animal of the bovine class should have a bell hung from its neck, so that no animal may stray without the fact being at once detected. The leaders of a flock of sheep should also have bells. The herdsmen, when out in the forest with their cattle, should not be allowed to carry any woodmen's tools with them; but in case they are allowed to lop, they may have with them light hatchets or bills. Infringement of rules on their part must be followed by heavy fines or summary expulsion from the forest, together with suspension, if necessary, from the privilege of grazing for a determinate period.

Lastly, in crops of mixed ages, especially if young growth is deficient, every assignment should be further divided into two or more equivalent portions and a rotation established, so that each area may have a certain period of rest.

When grazing is charged for, the fee per head to be levied for the different classes of animals should be regulated by several combined considerations, the principal of which are (1) their relative destructiveness from a forest point of view, (2) their relative value, (3) the quantity of fodder they consume, (4) the market value of the fodder, (5) the wealth of the general population, and (6) the degree of conservancy to be adopted. Thus, although a goat will eat less than a fifth of what a plains cow will consume, the respective fees to be levied should be considerably in excess of the ratio of 1 to 5. As so many different considerations affect the question of the amount of grazing dues, it would be absurd to adopt the same tariff of rates for a whole province or even for a whole district; and often even two neighbouring forests, which are under different degrees of conservancy, will require different rates. Similarly, the proportionate rates for the different classes of animals ought not to be the same everywhere. For instance, in the North-West Himalayas, the diminutive hill cow is hardly worth more than a sheep or goat, while in most other parts of the country the value of a cow is 4 to 10 times higher than that of a sheep or goat. The simplest way of reducing the number of animals of any class grazing in a given forest is to raise the grazing fee. Remembering this, if the grazing in any forest is in excess of its capability, we have only to gradually raise the rates until the number of cattle is

brought down to the desired figure; the effective rates in each case will depend on the wealth of the population and the value of the cattle. Sometimes, however, certain classes of people may have to be specially favoured, such as backward jungle tribes which are under our particular protection, or inhabitants of villages composed exclusively of our work-people; and in their case a limited number of animals per family or household may be admitted to graze at lower rates, only those in excess of this number being taxed according to the general tariff. The full rates at present levied in most provinces are far too low in comparison with the amount of fodder consumed and the value of the animals.

The levy of grazing dues gives, more than the collection of any other kind of forest revenue, special facilities for oppression and extortion, for there is scarcely a household in the neighbourhood of forests which does not possess at least one goat or cow. For this reason the arrangements for collecting the dues must be made with the greatest care. At the same time they should be such as not to engross the time of the establishment. The system will have to be different according to circumstances. For cattle which go to graze in the forests during the day and return to their villages at night, the plan which commends itself most is to require annual returns from the patwaris and headmen jointly, a few of these returns being checked, to test their general accuracy, by the forest staff. On receipt of the corrected lists, the dues should be collected by the Collector of the district in the same way as land revenue. In some districts a triennial census of such cattle is made, and a grazing assessment is fixed by villages for a period of three years, the amount assessed being collected annually by the district officials like land revenue. This is perhaps the simplest and least inquisitorial system that has yet been devised, but many changes may occur in the number of cattle in a village during the period of three years. For cattle which pass the night also in the forest, the forest staff must both count the cattle and collect the dues, unless the same cattle have been paid for through another channel, in which case the herdsman must come provided with a pass for the number of head already paid for. A copy or duplicate of such pass must be sent for check to the District Forest office.

## SECTION II.—HAY AND CUT GREEN FODDER.

The removal of grass means, just as in the case of grazing, the loss to the forest of so much precious manurial matter; but, in nearly every case, this disadvantage is much more than counter-

balanced by the benefits accruing therefrom. In frosty localities, if tall dense grass protects small seedlings, it, on the other hand, makes it very difficult for them to rise above it, as it increases by several degrees the intensity of the cold. Heavy frost will lie upon the grass in grassy land, when on bare open land the temperature may be several degrees above freezing. In the case of high temperatures, however, surrounding and overtopping grass is nearly always beneficial. For young seedlings struggling in the midst of grass, cutting the grass is a much better and surer means of getting rid of it than grazing, with all its attendant risks. On this account grass-cutting should be encouraged as much as possible wherever it will lead to a diminution of grazing. The closing of the forest areas in Ajmere against grazing has not only resulted in the possibility of growing forest on dry, bare, rocky hill-sides, but even in an increase in the production of fodder, so marked as to be freely recognised by the population itself, which clamoured most against the measure on its introduction only 15 years ago. But the grass-cutters must be warned to be careful not to cut off seedlings with the grass, and the use of scythes should be strictly prohibited.

Green grass from the forest can be used only by people living within the distance of a day's journey. Hence for a more general utilization of the fodder, it should be converted into hay, the preparation of which must, therefore, now be described.

Grass for hay should be cut immediately it is in full bloom. After this period, the formation of seed robs the stem and leaves of potash, nitrogenous matters, and phosphates, and the carbohydrates are converted into coarse fibre, so that the grass becomes poorer in nutritive substances and the proportion of indigestible fibre increases. Moreover, the further vegetation of the plant and the progress of fructification continue to exhaust the soil without any compensating advantage. At any rate, the grass should be cut before the seed is fully formed. As soon as the grass has been cut, it should be spread out to dry. If not dried quickly enough it would ferment, the sugar in it being converted into alcohol, which would both destroy its flavour and nutritive value, and cause it to lose the well-known fragrance of hay. The alcohol also dissolves out the green colouring matter of the chlorophyll, so that hay that has not been dried quickly enough is yellow and not greenish. At the same time it must not be dried too quickly, otherwise it becomes too hard and is not so nutritious and digestible as properly dried hay. On the approach of evening, the grass, now partially dry, should be collected into heaps, so that the

dew at night may not undo the work of the day. The second day after the grass has been cut, it should be tossed up in the air with forks, after it has been spread out with a rake and the dew has evaporated. If the hay is now ready, it should be carted away or stacked; otherwise it must be collected once more into heaps against the night, and tossed up again with forks for another day. Wet weather is of course disastrous for hay-making. Good hay is greenish in colour, appreciably dry, sweetish to the taste, and agreeably scented. The weight of hay is  $\frac{1}{3}$ rd that of the original grass.

To preserve hay it should be stacked, in order to protect it from wind, rain and dew, and, at low elevations, also from white ants. The ordinary Indian way followed in the plains is to tie up the hay in bundles from 1 to 3 lbs. each, which are piled up in stacks resembling either a house with a pent roof or a circular hut with a conical roof. The dimensions at the eaves in either case is greater than those at the base, in order to let the rain drop off on the ground clear of the hay. The former kind of stack is the easier one to build, especially when large stacks are required. Such stacks, containing 200,000 lbs. of hay, are not uncommon. After the stacking is completed, a roof of thatch should be put on. For the first kind of stack the thatch can be constructed on the ground and then put up and kept down with ropes heavily weighted at the ends, thereby also securing compression for the hay—another very important advantage gained by the adoption of that mode of stacking. For the supply of the army in cantonments Captain Wingate, the officer specially charged with the forage operations of the Western Commissariat Circle of the Bengal Presidency, recommends the following system of stacking. A circle is traced on the ground of the required diameter and encircled with a shallow trench, the earth from which is used to raise the ground inside. Above this earth is laid a 4 to 6-inch bed of cinders, which not only keeps out white ants and rats, but also prevents damp getting in from below. Before the grass is stacked, the site is dressed, so as to give it the form of a flat dome. The height of the stack at the eaves is about two-thirds of the diameter at the base, and the diameter there at least 6 feet in excess of the lower one. The stack is then finished off in the form of a cone with steep sides. It should not be thatched until it has settled. This takes about a fortnight, and in the meantime the hay is protected with tarpaulins. In the Himalayas, where space is always a desideratum, the stacks are usually built up loosely, in a more or less globular form, on pollards or in the crowns of trees in the midst

of the main branches. Well-kept hay will remain good for more than three years.

In many parts of India hay is pretty carefully made ; but not unfrequently the grass is cut when the seed is quite ripe, and even after the whole plant has become quite dry. No practice is more reprehensible.

Our forests could furnish the whole country side with excellent hay, and remove, once for all, the frequent great embarrassment experienced by the army in obtaining forage. But the disproportionate bulk of hay, compared with its weight, renders its transport difficult and expensive, especially with our high railway freights and deficient means of communication. Hence its export beyond two or three days' journey by cart has been hitherto impracticable. To remedy this very serious drawback, the practice has, since the last year or so, been experimentally resorted to of compressing the hay into bales weighing about a maund each and bound round with iron bands, just like a bale of cotton or piece-goods, or with iron wire, the latter requiring no rivets and being at least 2 lbs. lighter for each bale. This plan was very successfully followed in 1889 and 1890 in the Changa Manga plantation, when the entire outturn was taken by rail to the cavalry camp at Muridki, a distance of about 60 miles. The compression was effected with hand-worked Boomer presses, which are easily portable and readily put up. The advantage of compressed bales of fodder to an army in the field is incalculable ; and even in ordinary peace times their transportability and non-liability to spontaneous combustion will render them invaluable in large towns and cantonments, especially those situated at a distance from sources of supply. At Amritsar, in the Punjab, a large steam factory, containing several presses and managed by a rich company under European supervision, has been at work for the past three years.

Better than ordinary compressed fodder is fodder compressed in combination with some sweet glutinous substance, which, by filling up all air-spaces, converts the bale into a solid mass. Mr. Arthur Rogers, a railway mechanical engineer, who originally conceived this excellent idea, has patented a most successful process, in which treacle is used as the cementing substance. The treacle increases, to a marvellous extent, the nutritiousness and palatability of the fodder and makes it keep good for an indefinite period. Moreover, it makes use of the interstices which would otherwise only contain air, and thus helps to economise space. Some bales of Mr. Rogers' fodder were found totally unaffected after having been buried in the ground for three years.

## SECTION III.—GRASS PRESERVES.

It will be appropriate to say a few words here regarding the formation and management of grass preserves, a matter that has real importance for the Indian Forester in the neighbourhood of large towns and cantonments and in dry places on the North-Western frontier, where a ready supply of fodder for any military emergency is a necessity. We may have (1) unirrigated natural grass preserves, or (2) irrigated preserves. In both classes of preserves a sprinkling of deep-rooted trees with shady crowns helps the growth of the grass.

1. *Unirrigated natural grass preserves.*

The special maintenance of such preserves is to be recommended only when the rainfall exceeds 10 inches and the soil is at least of medium quality. The coarser grasses and weeds should be grubbed out; and if money is available, the land should once for all be ploughed up, top-dressed with well-rotted cattle droppings or pou-drette, and sown with seeds of the better kinds. The quantity of seeds to be sown will vary from 3 to 10 lbs. per acre, according to the species. Once established, the preserve requires only to be kept free of undesirable growth and top-dressed from time to time with manure. Grazing or the periodical cutting of the grass should never be entirely stopped, for there is no more effective and economical mode of improving the quality of the fodder and of keeping out coarse species than allowing moderate grazing at the proper seasons and maintaining the ground clear of dead tussocks. If cut fodder is required, as many as three and sometimes even four cuttings may be taken off during the first three months of the rains, the next crop being left, if necessary, to mature for hay. If the same area has also to serve as a grazing ground, grazing may be permitted during the first two months of the rainy season, and again after the crop of hay has been removed. Combined grazing and cutting is better than cutting alone, as the grazing makes the grass grow closer and the droppings of the animals constitute so much effective manure. Heavy or frequent manuring or any kind of intensive treatment is of course quite out of the question in natural preserves, except in the immediate vicinity of large centres of population. At Allahabad, off extensive unirrigated areas that have now been systematically treated since 1882, the yield of green grass is as high as 800 maunds per acre per annum.

2. *Irrigated grass preserves.*

Irrigation places in our hands an instrument which enables

every desirable species of grass to be cultivated in the greatest abundance possible. In this country we seldom, if ever, find any area that is covered at every point with only the best kind or kinds of fodder grass. Hence the first thing to do is to sow or plant up the land with good species, after levelling the ground and laying out the irrigation channels.

Certain kinds of grasses, especially those which spread by means of runners, may be planted; the rest are best sown at the rate of from 20 to 40 lbs. of seed to the acre, according to the species used. The usual method of preparing the land, which will probably never be superseded, is to plough it up and top-dress it with manure. This method can give in the very first year of cultivation as much as 600 maunds of green doob (*Cynodon Dactylon*) per acre. General Otley's system, which is said to increase the yield by at least 30 per cent. by giving eight cuttings per annum at the rate of 56 maunds of green grass each per acre, and to get rid of the soda efflorescence in reh soils, consists in excavating the soil to a depth of 18 inches, putting in a 9-inch layer of fresh litter or other manure and returning the earth, thoroughly sifted, over the manure. Finally, the area is divided off into beds 3 feet wide and enclosed by a ridge of earth to hold the irrigation water. The system has not yet had a fair trial, but it is beyond question a most costly one, and for that reason alone can never be generally adopted.

The land should be irrigated once every two, three, or even four weeks, the soil being flooded and thoroughly drenched each time.

It is evident that in irrigated preserves grazing cannot be permitted and the grass can only be cut.

#### SECTION IV.—ENSILAGE.

Silage is fodder obtained by storing green material under continued compression and exclusion of air.

The simplest method of making silage is to excavate a rectangular pit not less than 8 feet deep, in a stiff soil impervious to air. In order to pack the fodder close and thus diminish the quantity of air necessarily left in the pit, it should be chopped short and stratified, each stratum being well trodden down by men and boys before the next one is laid on. The thickness of the layers, when completely settled, should not exceed 3 inches, and the shortness of chopping will depend on the stiffness of the material to be ensilaged. If the temperature of the air is much under 95° Fah., a new stratum must not be put on until a certain degree of fermentation has occurred in the one previously laid down. This fermenta-



tion not only brings up the temperature to the right point, but as a direct result of the formation of carbonic acid, which is heavier than air, this last is driven out of the fermenting heap. If the temperature of the air is already high enough, the filling should be done quickly, but not so quickly as to prevent the contents from settling down and a certain amount of fermentation setting in. The pit should be filled with the fodder within about a foot of the top. The covering should consist of bamboo or other cheap matting, overlaid with sufficient closely-rammed earth to create a pressure of from 100 to 150 lbs. to the square foot. The contents of the pit will continue to subside, and with them also the covering, which should be constantly watched for cracks, until there is no further settling. Unless the contents are well compressed, they become overheated and the silage is rendered poor and uneatable. At the end of from three to six months the silage is ready for use, but it can of course be kept unopened for several months longer. The portions at the top and sides are nearly always over-fermented and not fit to be eaten, but all the rest is highly nutritious and wholesome, although it possesses a peculiar flavour and odour, to which cattle must generally become accustomed before they take to it.

A more elaborate method, which is, however, perhaps unnecessarily expensive, is to line the pit with masonry and cement, and effect the compression with planks and mechanical appliances.

What occurs in the pit while the silage is forming may be briefly described. Provided the temperature is not too high, minute organisms (ferments), the germs of which are enclosed with the fodder, grow and multiply rapidly. Under the action of these ferments certain acids, the most important of which are lactic and butyric, are formed at the expense of the carbo-hydrates present in the fodder. If air is not perfectly excluded, oxidation becomes too rapid, and the temperature rises high enough to kill a large proportion of the ferments, thereby arresting the formation of the two acids just named, so that *sweet* instead of *sour* silage is produced. Whichever kind of silage results, there is a loss of carbo-hydrates and of nitrogenous matters (especially of true albuminoids) and a consequent increase in the proportion of indigestible fibre. The total loss of solid matters varies from 24 to 28 per cent.

The difference between sweet and sour silage may be summed up thus. Sweet silage contains somewhat less water, a smaller quantity of acids (sweet silage from 0.02 to 0.1 per cent., sour up to 2 per cent.), and about  $\frac{1}{2}$  per cent. more albuminoids, but 2 per cent. less carbo-hydrates, and about 3 per cent. more undigestible fibre. Moreover, it does not keep so well as sour silage, and, when

given in large quantities to milch cattle, it taints their milk, although eaten in moderate quantities it improves it. On the whole, cattle take more readily to sour than to sweet silage.

Silage contains a smaller proportion of nutritive matter than hay; but, whereas hay can be made only with the finer grasses, the coarsest materials, that could not otherwise be utilised at all, can be ensilaged and rendered tender and palatable.

#### SECTION V.—LITTER.

From an agricultural point of view, litter is the dry absorbent vegetable material placed under cattle where they are stalled, with the object not only of giving the animals a soft warm bed to lie upon at night, but also and principally of collecting, for use in the fields, their droppings and urine. In India, grass and straw are, as a rule, so abundant that the leaves and stalks of other herbaceous plants are hardly ever used; and, indeed, the practice of littering cattle obtains on only a very small scale, owing both to neglect and to so large a proportion of the cattle being either sent out into the forests to graze, or folded together, almost as close as they can stand, in an open railed enclosure.

#### SECTION VI.—FIBRE.

Amongst herbaceous species, the most generally utilised for the fibre they yield are certain grasses, and a few species of Tiliaceæ and Malvaceæ.

None of our grasses yield any really textile material, their fibres being suitable only for making ropes, matting, and paper. The most important, as well as by far the most valuable, of our grasses are the bhábar (*Ischæmum angustifolium*) and the munj (*Saccharum Sara*).

The former grass grows gregariously on dry bare slopes along the foot of the Himalayas and in the hilly parts of Behar, Chota Nagpur, Western Bengal, and the northern districts of the Madras Presidency. The late Mr. Routledge, the great paper manufacturer of Sunderland, declared that "It closely resembles esparto but does not contain so much glutinous and amylaceous matters, nor so much silica. \* \* \* \* \* A small quantity of bleach brings it up to a good colour. The ultimate fibre is very fine and delicate, rather more so than esparto, and of about the same strength; the yield is, however, 42 per cent., somewhat less." Mr. Edwards, of the Lucknow Paper Mills, found the yield to be only a little more than 35 per cent., but the specimens he experimented with had been badly collected, the top parts of the plants being more than

usually perished. We have thus in this grass an extremely valuable paper-making material, but unfortunately our few paper mills are not yet capable of turning out the finer kinds of paper, and are situated too far away from the bhábar-producing tracts for the raw material to be landed at them at remunerative rates. For the present, therefore, bhábar is used only for making cheap ropes. Doing up the grass into well pressed bales will, no doubt, reduce very appreciably cost of carriage.

The munj grows in abundance in all moist low-lying places, especially those which are occasionally flooded every year. Its fibre, which is obtained from the long sheaths closely enveloping the stalk, is used both for rope-making and for weaving into very durable and handsome ornamental carpet-like mats which white ants will seldom touch.

Grasses required for fibre should be cut only when perfectly ripe and as soon as they are ripe ; otherwise the nightly dews which then prevail, followed by the hot morning sun, would produce incipient decomposition and weaken or destroy the fibre. Before export, the cut grass should be cleaned of all decayed and useless portions. It is a fact proved by experience that annual cutting not only keeps up the quality of the grass, but also increases the yield. If cutting is neglected even for one year, the production falls off in an astonishing manner. The annual burning of the grass also improves its quality, by rendering it finer and more fibrous ; but it is evident that the forest on the dry hill-sides affected by the bhábar grass cannot be burnt with impunity.

Amongst the herbaceous *Tiliaceæ* the most important fibre-producing species belong to the genus *Corchorus*, two of which, under cultivation, furnish the jute of commerce. All the wild species yield valuable fibre, but their utilization has hitherto been only local. Like the fibres of the mallow family next mentioned, the fibres are all textile and also make good cordage and paper. They deserve very much more attention than they have hitherto received.

In the mallow family, the herbaceous fibre-yielding species belong to the genus *Hibiscus*, and to them may be added the *Malachra capitata*.

The fibres of the plants belonging to both the above-mentioned families are generally anastomosed, but they are joined together so lightly as to be easily separated by a short period of maceration in water. Plants collected before flowering occurs, yield a finer and more silky fibre than they do later on ; but the strongest fibre is obtained when they are in fruit. The fibre must be extracted at once, otherwise fermentation sets in and deterioration ensues.

## SECTION VII.—MATERIAL FOR THATCHING AND MAT-MAKING.

More than half the population of the empire live under thatch roofs, and nine-tenths of this enormous number under thatch composed of grass, used either by itself or with leaves packed in between, in order to secure more perfect tightness combined with lightness. The durability of grass under complete exposure to the sun and atmospheric influences is in direct ratio to the proportion of hard fibre it contains, and in inverse ratio to the quantity of sugar, starch and nitrogenous matters in it. Hence tough fibrous grasses are the best for the purpose, and no thatching grass should be cut until the seed has ripened and the stalks have begun to dry. After it has been cut, the grass cannot be dried too quickly and put away under shelter from dew and rain. The sooner it is used, the better.

For matting, the stalks of both sedges and grasses are employed after they have been deprived of their leaves. The most suitable species are those which have long, straight, well-silicified stalks, with sufficient fibre to prevent their being brittle. Like thatching grass, the material for matting should be cut only after the seed has ripened and the stalks are nearly dry. The matting made is not only used for covering floors, but also as a ceiling immediately under thatch roofs. It is also, when stiff enough, sometimes used directly for roofing, and especially for putting over open carts and stage coaches during the rainy season.

Another use made of the stalks, besides mat-making, is in the manufacture of "chicks." With the thick lower portion of the stalks of the large *Saccharums* are made the chicks commonly hung round verandahs in Northern India. In the Indian mode of paper manufacture a fine grass chick takes the place of the wire netting on which the half stuff is caught in becoming a sheet of paper.

## SECTION VIII.—OTHER USES OF HERBACEOUS VEGETATION.

Numerous species are eaten by man as a vegetable, some of them being equal to the best kinds grown in kitchen gardens. Many others supply useful drugs, while some are used in the indigenous arts of the country. Two species of lichens, *Rocella tinctoria* and *R. fuciformis*, yield the *orchella* of commerce, which gives on treatment with lime, carbonate of potash and urine, a very valuable blue dye (litmus). Dyers use it also to produce crimsons. Khas-khas tatties and chicks, made of the roots of *Andropogon muricatum*, are well known. The demand for these various species is, however, as yet too limited for any special reference to be made here regarding the mode of harvesting them.

## CHAPTER II.—UTILIZATION OF THE FLOWERS AND FRUITS OF TREES AND SHRUBS.

THE abundance and quality of flowers and fruit depend upon the exposure of the bearing trees to light. Some of the plants which produce saleable fruit and flowers either grow naturally in open places, or, being climbers, or trees towering above their companions, require no help to obtain the necessary amount of light. In all other cases thinnings must be made round every promising individual, both before the bearing age in order to promote its growth, and during this age to cause it to extend its crown and produce a large crop of flowers and fruit. When possible, trees furnishing valuable produce should be pruned just after a crop has been collected. The extent to which the flowering and fructification of any species should be encouraged will, of course, depend on the demand to be met, the prices to be obtained, and the relative value from both an economic and financial point of view, of the flowers or fruit, or both, as compared with timber and firewood.

In order to collect flowers and fruit, the ground under the trees should be kept perfectly clean, as, even if the produce is to be plucked off standing trees, a large proportion fit to be utilized will always drop on the ground. Flowers and fruit that require to be dried for the market should be at once spread out in an airy place and turned from time to time in order to prevent fermentation. They should also be preserved from rain and dew. When it is the seed that is wanted, the fruits should be treated as described in the Manual of Sylviculture. Occasionally, only the kernels of hard seeds find their way into the market; the quickest way to get rid of the shells is to pass the seeds between mill-stones kept sufficiently far apart to avoid breaking the kernel. When the shell is soft, instead of the upper mill-stone, a properly moulded mass of stiff clay may be used.

Flowers and fruit serve various purposes. Some are eaten by man or beasts, *e.g.*, the flowers of the Bassias (eaten raw or cooked after being dried; also yielding by fermentation and distillation a spirit resembling gin), *Bauhinia variegata*, &c., the fruit of the olive, *Salvadora*, Cashew, *Zizyphuses*, *Artocarpuses*, &c., the seed of the *Pinus Gerardiana*, *Buchanania latifolia*, &c. In years of gregarious fructification, which are often years of drought and

scarcity, the seeds of the various bamboos afford food to the forest population. Others yield dyeing and tanning extracts, such as the flowers of *Woodfordia floribunda* (colours leather red and contains 20½ per cent. of tannin), *Butea frondosa* (yellow and orange colours, much used at the *holi* festival), *Nyctanthes Arbor-tristis* (yellow), tun (yellow), &c., and the various myrabolams, and the fruit of *Mallotus philippinensis*, &c. The beleric and chebulic myrabolams, which are most valuable when gathered just before they are ripe, contain 30 to 50 per cent. of gallo-tannic acid, producing a soft and porous leather of a bright yellow colour. In 1880 the exports of myrabolams from Bombay and Kurrachee to London amounted to 235,000 cwts., valued at £180,000. In 1888-89 the quantity of myrabolams carried by rail and river in India, exclusive of Burma, exceeded 500,000 maunds, and was worth, in round numbers, 12 lakhs of rupees. From a third class of flowers and fruits oil is expressed or distilled, *e.g.*, the flowers of the various scented grasses, of jessamine, &c., the seed of the Bassias, the sál, olive, apricot, &c.

The oil of the Bassias and of sál is obtained by expression after boiling the seed and removing the hulls, the yield of oil being 40 to 50 per cent. of the weight of the hulled seed. The oil of all these species congeals at a lower temperature than ghee, which it resembles when solid, and which it is often used to adulterate. Numerous flowers and fruits are used medicinally, *e.g.*, the flowers of *Acacia Farnesiana*, &c., and the various myrabolams and the fruit of *Podophyllum*, of *Cassia Fistula*, *Strychnos Nux-vomica*, &c. A few kinds of fruit have special uses, such as clearing water (*Strychnos potatorum*), washing (the soapnut, *Acacia concinna*), poisoning water for fish (*Randia dumetorum*), &c. The fruit of the genus *Bombax* and *Calotropis* yield fibre which makes a soft stuffing for pillows and, in the case of one species, can also be spun.

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### CHAPTER III.—UTILIZATION OF THE BARK OF TREES AND SHRUBS.

THE principal uses of bark are for tanning and dyeing, and for furnishing fibres and drugs. On a small scale, it is also employed as covering material, as fuel, and for some minor industrial purposes.

#### SECTION I.—BARK FOR TANNING.

Tannin is the generic name given to a large class of organic bodies, mostly uncrystallizable, which often differ widely in chemical composition and reaction, but have the common property of precipitating gelatine from its solution and forming insoluble compounds with gelatine-yielding tissues. By virtue of this property they convert animal hide, which is easily putrescible, into insoluble imputrescible leather. They all form blackish-blue or blackish-green compounds with ferric salts, and when treated with alkalis, they give solutions which oxidize rapidly, usually becoming successively orange, brown, and black. Associated with catechu-tannic acid a white crystalline body is found, called catechin, which does not precipitate gelatine. The tannins are met with chiefly in parenchymatous tissues, especially in bark and young wood, in the pericarp or other coverings of green fruits, and in the excrescences called galls. Leaves that darken in drying, like those of the tea plant, of *Anogeissus latifolia*, &c., are rich in tannin.

From the tanner's point of view, tannins may be divided into two principal classes, *viz.*, those which produce a light fawn-coloured deposit (the bloom) on leather and those which do not. To the first of these belong the tannin of myrabolams, to the second the tannin of cutch.

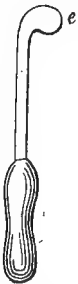
Tannin is a substance so easily soluble in water that bark intended for it has to be taken off with the greatest care. Bark may be removed (1) from a standing tree, or (2) from fresh-felled wood, or (3) from wood that has become more or less dry. In the first two cases it should be possible to strip the bark off the wood without difficulty; hence the barking must be effected when the union between the bark and wood is weakest, that is to say, at the beginning of the season of vegetation, from the moment the buds begin to swell up to the time the leaves attain their full size. During this period, the cambium is exceptionally active, and the tissues

on either side of it are soft and gorged with sap, so that the bark can then be separated from the wood easily. Moreover, owing to this special activity, the liber also contains at this time its maximum amount of tannin.

The only portion of the bark which contains tannin in useful quantities comprises the living layers; the dead bark is practically of no value at all. Also, owing to the great solubility of tannin, the moment the periderm begins to split and a rhytidome to form, rain and dew both reach the living layers through the cracks and wash out a large proportion of the tannin. Hence the best stems for the tanner's purpose are those of vigorous growth which have still a smooth uniform shining bark. When this period of growth is past, the yield of tannin diminishes considerably. According to Mueller, as quoted by Gayer, the bark of young poles contains twice as much again of tannic acid as the bark of full-grown trees. The best stems are unquestionably young coppice poles, and coppice worked for tanning bark should be exploited on short rotations. The great drawback in the case of bark which contains a considerable proportion of dead rhytidome is that this latter *must* be got rid of, always with immense trouble, before the bark can be used. The rhytidome without appreciably increasing the amount of tannic acid, introduces a large quantity of undesirable colouring matters into the tanning liquor.

The removal of bark from standing stems (technically termed *peeling*) is thus effected. With a sharp broad-bladed hatchet or a curved bill the bark is cut through round the base as far as the wood. A similar cut is made 3 or 4 feet higher up. Then with the tool represented in *Fig. 62*, which is very sharp along the edge *e*, a straight incision is made from the top cut to the bottom. The bark on each side of the incision may now be lifted off with

Fig. 62.



Bark scalpel.

ease with the extremity of the same tool or with the ordinary *khurpa* of the Indian gardener. After this, the workman has only to gradually strip off the entire cylinder of bark, aiding himself with the tool wherever it adheres too firmly to the wood. In this manner he peels off successive complete rolls of bark until the entire stem and the thicker branches, if any, have been laid bare. This method of barking is evidently unsuited for large trees. Moreover, it is the most troublesome of the three methods, and should, therefore, be employed only when the stems to be peeled cannot, for some reason or other, be felled at once.



In the second method, the bark is stripped off immediately the trees have been felled. The tree may of course be of any size. If the stems are small enough to be rolled about, they may be peeled in the same way as standing poles, the bark being taken off in complete rolls. In the case of larger stems, the bark must necessarily be pulled off in narrow strips like semi-cylindrical tiles; the bark being thick, with a hard rhytidome, all the incisions must be made with an axe, and in order to loosen it, it has often to be beaten with the back of the axe.

In the third method of barking, the tree is cut up into billets, and at any time after the tree has been felled, the billets are exposed to the action of steam, under which the bark swells up and is easily detached. It is evident that only comparatively thin wood can be peeled in this manner. Ordinary steam, owing to the solubility of the tannin, injures the quality of the bark, and hence the best apparatus are those in which superheated steam is used. Portable apparatus, weighing less than 600 lbs., have been constructed, which, with the labour of only four individuals, give an outturn of more than 2,000 lbs. of bark a day. The researches of Grandeau have proved that the steaming does not affect at all the yield of tannic acid.

Under ordinary circumstances the bark itself is exported after being dried, in order to reduce its weight and volume and to prevent fermentation. Air-dried bark is only from one-half to two-thirds the weight of the green bark. The diminution of volume resulting from air-drying varies from 20 to 40 per cent. To dry the bark, the rolls are stood up close together against one another in the form of a pent roof, a line of rolls being placed along the top like ridge tiles; or they are piled up in a single row, in low stacks, on trestles raised at least a foot from the ground. In fine weather they become sufficiently dry in two or three days. Heavy rain is fatal to the bark, and hence, unless the steaming process is resorted to, drying in the open is out of the question for most of our Indian species, since their growing season is ushered in with continuous wet stormy weather.

To obviate this very serious drawback, it is matter for consideration whether it would not be best to fix the season for felling without reference to the production of tannin, and to extract the tannin at once, thus exporting the extract instead of the very much more voluminous and heavier bark. The extract could be either dry and solid or a thick liquid. In either form the tannic acid would keep for ever, whereas in the bark it disappears in the course of two years in spite of the utmost precautions, and com-

bined great heat and humidity, such as obtain in the hold of a ship, would cause it to decompose in a much shorter time. This plan would save cost of packing and carriage in a very remarkable degree, so that our forests, in which thousands of tons of bark now go annually to waste, could supply not only local tanners, but tanners in the most distant countries.\* To Captain Wood is due the credit of attempting to introduce this practice into India and thereby utilizing the vast resources of our forests in tanning bark. He has experimented with *sál* and *Terminalia tomentosa*. The bark is chopped up in pieces about 4 inches square and boiled in earthen pots, the strained liquor being completely desiccated or reduced to the consistency of treacle. The extract prepared by the Oudh Forest Department has the defect of containing too much dark colouring matter; but this is, no doubt, due in a great measure to portions of the dead bark having been boiled with the lighter-coloured living bark, a practice to which must also be attributed the very poor outturn in tannic acid (only  $2\frac{1}{2}$  per cent. of the dry weight of the bark). With a proper system of manufacture, the yield would be at least doubled, and the percentage of tannic acid in the desiccated extract would certainly reach 50, instead of only 33, as at present. The price of chestnut wood extract, containing 30 per cent. of tannic acid, varies in London from £12 to £15 a ton. There is no reason to suppose that a great many of our

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\* The practice of preparing a tanning extract by boiling chips of wood of the sweet chestnut is a very old one, and for many years now the system has been very successfully applied to oak wood in Europe. Within the last 30 years an extract of the hemlock (*Abies canadensis*) bark has taken the place of the crude bark in the exports from Canada and the United States. The mode of preparation is an instructive one for us in India, who have to devise some way of turning to profitable account the thousands of tons of bark which go to waste every year. The bark, in pieces  $\frac{1}{2}$  to 1 inch thick and several inches long, is soaked for about 15 minutes in water at 200° Fah. It is then fed into a hopper, which conducts it to a 3-roller machine, something like a sugarcane mill, through which it passes, coming out lacerated and compressed. It next falls into a vat of hot water, where it is agitated by a wheel in order that the tannin from the crushed cells may be dissolved in the water. Hence it is raised by a series of buckets, on an endless chain, to another hopper, whence it is fed to another 3-roller mill. Here it receives its final compression, and comes out in flakes or sheets, like coarse paper, and almost free from tannin. The buckets are made of coarse wire, that the water may drip through. To avoid the blackening action of iron, wherever this metal is brought into contact with the solutions, it is thickly coated with zinc. The solution is evaporated to a solid consistency, generally in vacuum pans. About 2 tons of bark yield 500 lbs. of extract, containing 18 to 25 per cent. of a deep-red tannin, giving considerable weight and firmness to leather.

gregarious trees would yield a worse commercial article than this latter extract, and we thus only require capital and enterprise to enable our tanning materials to compete successfully in all the markets of Western and Central Europe with such materials from other sources of supply. If caste prejudices militate against the expansion of the tanning industry in India and the local conversion into leather of the shiploads of raw hides which leave the country every year, they cannot be a bar to the preparation of tanning extracts.

We have as yet no figures for the proportion of tannic acid contained in the barks of our various species. Even in Europe the figures are few and contradictory for the three or four species used. In France a quantity of acid varying from 5 to 7 per cent. of the dry weight of the bark is considered good. In Germany the best bark is said to yield 16 to 20 per cent. of its dry weight of tannic acid. But the practical tanner does not value bark only by the quantity of tannic acid present in it. Even in one and the same tree the bark is prized more highly by him, the lower it is obtained from the tree, although the bark from the upper portion of the stem is, as a rule, very much richer in tannin than that from the base. The commercial and practical value of a tanning material depends not only on the quantity of tannin present in it, but also on the character of the leather it produces, whether hard or soft, dark or light-coloured, and heavy or light.

The volume of the bark varies from one-third to one-eighth that of the original unbarked wood, according to the age of the portion or the tree from which this latter has been taken. Hence the barking of firewood diminishes very appreciably both its weight and volume. On the other hand, the peeled wood always commands a relatively higher price, while the value of the detached bark, if there is any regular market for it, will, after deduction of the cost of removal, drying, and separate export, always exceed the net depreciation suffered by the firewood in consequence of loss of weight and volume due to the peeling.

Some of the best known barks used by tanners are those of *Acacia arabica*, *Terminalia tomentosa*, *Cassia auriculata*, *Rhus Cotinus* and *Rhus mysorensis*, *Garuga pinnata*, *Zizyphus xylopyra*, *Buchanania latifolia*, *Bauhinia purpurea* and *Bauhinia variegata*, *Albizia procera*, alders, *Quercus incana*, and *Phyllanthus Emblica*.

Tannic acid is not the only product from the bark of trees that serves the purpose of curing leather. The well-known softness, peculiar scent, and water-proof quality of Russia leather are due to

its being impregnated, after it has been tanned, with the essential oil distilled from the outer white bark of the birch. Amongst our numerous species some are sure to be found capable of yielding a similar oil.

#### SECTION II.—BARK FOR DYEING.

Irrespective of tannic acid, which with salts of iron gives various shades of green, purple, maroon, grey, and black, almost all our barks yield, by mere decoction, a large proportion of other colouring matters, some of them red and yellow, but most of them giving some shade of brown. Contrary to tannic acid, most of these colouring matters reside in the rhytidome, so that the older a tree is, the larger will be the amount of colouring matter present in its bark. It is principally these colouring matters which cause a difference in the colour of leather, according to the species of bark used. Up to the present, scientific dyers have not taken up a study of our various tree-barks, and hence their capabilities as dyeing materials for use on a large scale are still only a matter for the future to reveal. All the dyes are permanent. That these dyes are likely to be greatly fancied the moment they become known seems certain from a casual use of the brown dye obtained in bleaching the fibre of *Bauhinia Vahlia*. Mr. Wilson, the gentleman who experimented with the fibre in England, employed the colour in dyeing silk, and produced some elegant shades by different reactions. The bark of *Acacia arabica*, *Hardwickia binata*, *Soymida febrifuga*, *Terminalia tomentosa*, and *sál* are well known to yield extremely rich browns.

#### SECTION III.—FIBRES.

All woody species yield fibre, but there are only a very few, of which the fibres are strong enough to be twisted without breaking, and the number is still smaller of those the ultimate fibres of which, remaining after the completion of the cleaning and bleaching processes, are long enough to be spun. All fibres suitable for cordage and spinning are also excellent for paper-making, for which a great many others also are well adapted. The fibre of the living bark alone is fit for use. The woody species whose bark yields utilizable fibres belong almost exclusively to the Malvaceæ (*Hibiscus*, *Thespesia*, *Kydia*, *Adansonia*), the Tiliaceæ (*Grewia*), the Sterculiaceæ (*Sterculia*, *Helicteres*, *Eriolaena*), the Urticaceæ (*Bæhmeria*, *Pouzolzia*, *Sarcochlamys*, *Maoutia*, *Debregeasia*, *Broussonetia*, *Antiaris*, *Ficus*, *Ulmus*, *Sponia*), the Leguminosæ (*Sesbania*, *Desmodium*, *Bauhinia*, *Hardwickia*), and the Asclepiadææ (*Calotropis*, *Marsdenia*, *Pergularia*). *Careya arborea* and *Daphne papyracea* are two well-

known exceptions to this rule. Amongst the Monocotyledons several palms yield fibre.

In all the dicotyledonous species the bark has only to be stripped off in as long ribbons as can be taken off, a certain amount of pounding or beating being necessary to loosen it. In the case of *Bauhinia Vahlia*, however, owing to the peculiar structure of the stem, the stem has first to be first split up into long thin strips, and then pounded until the bark separates from the numerous enclosed wood-strands.

Among the woody Monocotyledons, the chief of our fibre-yielding species are the cocoanut palm, from which we obtain *coir* (the fibre surrounding the nut) and the fibre of the leaves and sheathing leaf-stalks, and the *Caryota urens*, the leaves and sheathing leaf-stalks of which give the strong *Kittul* fibre, which is made into ropes, brushes, brooms, baskets, &c. The cord-like fibre obtained from the interior of the stem of the cocoanut, palmyra, *Caryota*, and other palms, may also serve important uses.\*

#### SECTION IV.—OTHER USES OF BARK.

Many barks are used for medicinal purposes, owing chiefly to the alkaloids they contain. The most universally used of such barks is that of the various *Cinchonas*, which, although exotics, are now cultivated on an extensive scale in plantations treated mostly on the coppice system on very short rotations. Some barks are used for special industrial purposes, those containing gelatinous secretions or tannic acid serving, in many cases, for clarifying sugar. The gelatinous matters coagulate with heat, thus separating from the liquid and carrying away with them the minutest impurities, while the tannin, by coagulating the albuminous matters present, has the same effect. The bark of the *Acacia leucophlœa* is used in the distillation of spirits, the tannin causing the albuminous matters to be precipitated.

Exceptionally, mere temporary huts are sometimes covered with bark, and cheap umbrellas in Upper India are made with the bark of the *Bhojpattra*. Moreover, the thick corky bark of *Pinus longifolia* is made into charcoal, which is more highly prized than wood charcoal by blacksmiths in the Western Himalayas.

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\* This paragraph should have appeared in a different place. It will do so in another edition.

## CHAPTER IV.—UTILIZATION OF THE LEAVES OF TREES AND SHRUBS.

THE leaves of trees and shrubs are used principally for fodder, manure, litter, and thatching. On a smaller scale they yield drugs (nim, *Vitex Negundo*, senna, *Adhatoda Vasica*, &c.), material for dyeing (*Indigoferas*, *Lawsonia alba*, &c.), and tanning (*Anogeissus*, *Rhus*, &c.), and for matting, basket-making, and paper manufacture (various palms). The number of species which serve these last mentioned purposes is, however, so small, and the quantity of leaves that is actually used, or is ever likely to be required, is so insignificant, that arrangements for meeting the demand for them, without injuring the stock or the resources of the forests, will never present any difficulty.

### SECTION I.—LEAVES FOR FODDER.

For fodder, leaves must of course be plucked or lopped green, as otherwise they would have no nutritive value. Moreover, the leaves of most fodder-yielding species are relished by cattle only while they are young and tender, since they afterwards either become too tough and fibrous or acquire an unpleasant flavour. It is scarcely necessary to say that only broad-leaved species yield fodder.

The nutritive value of tree-fodder, as compared with that of the best meadow grass, is as 100 to 125. Lopped twigs and small branches contain from 40 to 60 per cent. by weight of leaves and edible stem-portions.

The practice of lopping is always harmful. Besides robbing the plants of assimilating organs and causing disfigurement and introducing the germs of unsoundness, it deprives the soil of manure more valuable than that furnished by the grass growing under them. This higher value is due to the leaves being less fibrous and decomposing more readily, and also to the fact that the total mass of leaves produced by canopied trees is larger than the entire quantity of grass growing below. Moreover, leaves are extremely rich in nitrogen and contain up to 8 per cent. of ash, a very large proportion of which consists of potash and phosphates. When wood alone is utilised, nearly all these constituents, which have been collected and brought to the surface by the roots from an im-

mense thickness of soil, are left on the surface to enrich it, and the same matter is thus repeatedly used, year after year, by successive generations of trees. If we remember this fact, and also that it is the dead fallen leaves alone which can, by their decomposition, draw fresh supplies of nitrogenous substances from the atmosphere, and convert refractory compounds of potassium, calcium, and magnesium present in the soil into soluble and assimilable constituents of plant-food, it is evident that the continued removal of the leaf-production of an area injures it not only in the present, but even more so also for the future, and that the injury is greater in proportion to the natural infertility of the soil. Sooner or later, the evil consequences of removing leaves become apparent in the languishing growth of the forest. In a sandy soil, the most careful conservation in other respects will fail to make the trees attain their normal size or grow close enough together to form a leaf-canopy. In very rich soils, the trees may still attain their usual size and form a dense growth, but at a comparatively early age they will begin to decay at the centre, so that they will be unable to furnish timber of any size.

The evil effects of lopping are thus extremely grave and incontestable, and yet we have to permit its continuance in many of our forests in consequence of admitted prescriptive rights. In the higher ranges of the Himalayas, the maintenance of these rights is doubtless unavoidable on account of the severity of the climate during the winter and early spring, when the leaves of trees are almost the only kind of fodder available. But in all other places the right of lopping for fodder is totally unjustifiable, as it only gives encouragement to improvidence. It is true that the leaves of trees are actually lopped only when the grass on the ground is dry and wanting in nourishment, but the same grass might have been cut in time and converted into hay, and therefore wholesome nutritious fodder, in anticipation of the coming dry season.

No effort should therefore be spared to suppress, whenever possible, the practice of lopping. Where we are powerless to stop it entirely, it should at least be restricted within the narrowest possible limits, and be regulated on lines having for their objective the safety of the trees lopped. In forest regions rich in species, there will nearly always be many kinds which are more or less useless from the point of view of timber and firewood, but which yield good fodder. Every endeavour should be made to confine the lopping to such species, and even then the lopping should be effected only in such a way as to maintain, to the fullest extent possible under the circumstances, the productive power of the trees lopped.

A tuft of foliage at least 5 to 10 feet deep, according to the height of the trees, should be left, and the branches below this level should be cut, with sharp tools, with a clean section, in order to prevent unsoundness and to enable the buds at the base to throw out new vigorous shoots. If the quantity of leaf-fodder to be furnished is large, a regular rotation of from 2 to 5 years should be established, the forest being divided into as many blocks, of which only one at a time is kept open for lopping. Advantage should be taken of the trees and poles to be removed in the ordinary course of fellings, by allowing them to be lopped for several years preceding their exploitation, thus furnishing at once a not inconsiderable portion of the total amount of fodder required. In coppiced forests, the entire stock of a coupe may be lopped just before it is felled.

When the amount of lopping admissible is very heavy, and it is found difficult or impossible to regulate and control it without serious injury to the forest, the best plan is to set aside a portion of the area exclusively for fodder purposes, and in this area to pollard the trees, either every year or after the lapse of a recurring number of years, according to the system of pollarding adopted.

The leaves of trees and shrubs, like grass and the leaves of pulso crops, may also be dried and stored up for future use. The leaves of various species of *Zizyphus* are used in this way. As a rule, dried leaves make very poor fodder for cattle, but sheep eat them with avidity and thrive on them.

## SECTION II.—LEAVES FOR MANURE.

The practice of using vegetable ashes as manure for field crops is one that dates from pre-historic times. The original inhabitants of India probably grew nearly all their crops in forest clearings in the ashes of the felled trees and other vegetation. In spite of injunctions in the Vedas to save forests from fire, the Aryans adopted the customs of the aborigines in the hilly regions where forest vegetation grew in luxuriance. Even in the plains, where cultivation made rapid progress, the idea that leaves and branches supply valuable ash was not forgotten, and the jungle was cut and spread over the fields, where it was burnt. In this manner, prescription has established rights which the present Government has in most cases, with certain restrictions, admitted. The exercise of such rights being more universal even than lopping for fodder, and one that is, in the opinion of the people and a powerful section of the official class, identified with successful agriculture, is so



much the more difficult to suppress, although it is utterly indefensible and is always followed by the gravest consequences.

The only system of using tree-loppings for manure, of which any serious defence has ever been attempted, is that called *rab* in the Konkan districts of Bombay and *beta* on the Malabar coast and in Mysore. It prevails especially in districts where the wet cultivation of rice is practised and the seedlings are transplanted from a nursery, and consists in preparing the seed-beds by burning layers of cowdung or brushwood with subordinate layers of leaves, grass, rice straw, and earth, in other words, in using a kind of surkhí ash for manuring the seed-beds. For this system it is contended that it is the only one which gives good and certain results in the peculiar circumstances in which those districts are placed. These circumstances are (1) the absence of heavy showers before June, when it is necessary to raise the seedlings if they are to be really strong at the time of transplanting; (2) the very heavy early rainfall; (3) the heavy continuousness of the early rains; (4) the early closure of the rains; (5) the absence of rain from the North-East Monsoon; and (6) the absence of facilities for water-storage. Owing, it is said, to these peculiar conditions, seed cannot be sown until the rains have set in, and the seedlings have to be forced, so as to enable the crop to mature within the short period during which the rain continues. Professor Wallace of Edinburgh has lent his powerful name in support of this system, but by merely re-echoing the opinions he heard in Bombay. There is really no reason why the rice cannot be forced by other means. A very simple expedient, which would help very much to shorten the time the crop would require to be on the ground, would be to force germination before the seed was sown.

In Southern India sugarcane fields are also often rabbed on account of the large quantity of manure required by this class of crop. A system of *rab* was once largely practised in parts of Central Europe and supported by arguments just as specious as those now employed in India; but these arguments could not stand before the march of science, and what was once considered a necessity has now received unqualified condemnation on every side.

Even if we assume, for the sake of argument, that the burning of leaves on the surface of seed-beds is necessary, it is impossible to understand why dead fallen leaves should not fully serve the purpose. Whether we burn the leaves taken off green or collected only after they have been shed naturally, the ash constituents left behind, after the burning, are practically the same. But, on the other hand, for the forest itself, the removal of green leaves means

arrested vegetation and the irretrievable loss of all proteid matters and starch, besides whatever other useful combustible constituents dead leaves contain. There is hence no reason why lopping for rab should not be stopped, even if vigorous rice seedlings cannot be produced without burning leaves on the surface of the beds, for dry leaves could take the place of the green material. The only excuse for rab thus seems to be that the green leaves, being attached to the branches, are more conveniently collected and carried than dead fallen leaves.

In the outer Himalayas, loppings of broad-leaved trees are spread over ginger and turmeric fields as a mulching to keep the soil loose and warm. At the same time they enrich the soil by their decomposition. But there is no reason why a mulching of straw would not be as effective, while the manurial properties of the leaves could be made good by applying an additional quantity of other manures.

The day must come when, with the march of progress and wealth, this very primitive practice of using the leaves of forest trees for manuring fields will be discontinued, just as the barbarous system of clearing and burning the forest for cultivation has already given place to settled agriculture. Until then, however, we must resign ourselves to arrange for its continuance with the least possible injury to our forests. In the first place, whenever we can do so, we ought to substitute dead fallen leaves for green lopped branches. In the next place, the practice should be rigidly excluded from all areas intended for the production of timber. In fuel forests, the adoption of the coppice system on short rotations should be taken advantage of to furnish a large supply of small branches and leaves at each exploitation; and to save people from coming long distances, there should be numerous small working-circles. The establishment of such small circles of course means excessively detailed work and a large staff, and therefore heavy expenditure. But Government must be prepared to face these drawbacks, if it rules the continuance of the cause thereof. In mere grazing reserves, the same rule must be adopted as for fodder-lopping, namely, restriction of the lopping to definite species and maintenance of a crown at least 5—10 feet deep. Where there is a mass of low shrubby vegetation, such vegetation may be cut back once every two or three years, a short rest being given to enable the soil as well as the root-stocks to recover.

The regulation of the removal of dead fallen leaves and the influence of the practice on the forest are described in the next Section.

## SECTION III.—LEAVES FOR LITTER.

The leaves of broad-leaved species, when they die and fall off, become so brittle and rot away so quickly, that the only dry leaves that can be used for litter are the fallen needles of conifers. When the leaves of broad-leaved species are cut green and then dried and spread under cattle, the object is more that of providing fodder and of using the leaves directly as a manure than of obtaining an absorbent medium for the easy and convenient collection of the droppings and urine of the animals. Thus nothing more need be said here regarding the use of the green leaves of trees and shrubs than what has already been given in the immediately preceding Section, and consideration must hence be limited exclusively to the utilization of conifer needles.

The needles of the *pine* tribe, as they contain the largest proportion of fibre, are the best adapted for litter. On the other hand, the needles of the other species of conifers which grow on an extensive scale, namely, the firs and deodar, and in certain parts of the Himalayas, also the larch, yield almost as much ash as the leaves of most broad-leaved species, and have, therefore, a high intrinsic manurial value.

The sweeping away of the entire annual fall of leaves is obviously fatal to the productiveness and maintenance of the forest. But since conifer needles decompose very slowly, and, unless crushed by artificial means, form a thick covering over the ground which prevents all reproduction by seed, the raking away of a portion of the annual fall is more beneficial than hurtful. The operation in question not only diminishes the thickness of this obnoxious covering, but also helps to crush whatever portion of it is left unre-moved.

The injurious effects following the removal of the layer of dead leaves covering the soil are greatest (1) on sloping ground, especially exposed hill-sides, since the soil there requires all the protection that can be given it to prevent erosion and impoverishment by the rapid downward filtration of water ; (2) on bad soils, in a forcing climate, with naturally quick-growing species, and in youth and in old age, for in all these cases the presence of a large quantity of plant-food in the soil is an absolute necessity ; (3) in open forest, where of course every bit of the exiguous annual leaf-fall must be preserved ; (4) in coppice, in which class of forest the soil is more or less completely exposed during half the rotation, so that the protection of the fallen leaves is an absolute necessity during that half, and their preservation and conversion into humus under the

leaf-canopy during the other half is the only means of maintaining the productiveness of the soil ; and (5) during the season of vegetation, when the soil must be in the most favourable condition possible.

In regulating the removal of dead leaves, two precautions must never be omitted : (1) a rotation must be established, and (2) measures must be taken to ensure a part of the annual fall being left on the ground. The length of the rotation will depend, principally, upon the nature of the soil and locality and the largeness of the demand, and, secondarily, upon the component species, the age of the crop, and the method of treating the forest. The more unfavourable the soil and locality and the heavier the demand, the longer must be the rotation. So also a young or an old crop, an exacting species, and a system of treatment which exposes the soil for long intervals, will require a long rotation. The saving of some portion of the annual leaf-fall is ensured by allowing the dead leaves to be collected only *while* they are falling and *only during the first half of this period*. A combination of the two precautions in question will never fail to result in a considerable quantity of leaves being left on the ground to decompose and form humus and enrich and improve the mineral soil below.

#### SECTION IV.—LEAVES FOR THATCHING.

Where palms grow in abundance, the leaves often form the entire thatching put into a roof. Before using the leaves, they should be placed over one another, on a dry floor, with the leaflets properly spread out, so that they may dry quickly and well flattened out. When dried thus, they are easily arranged over one another in the roof. If the leaflets are long and narrow, like those of the coconut palm, they may be plaited together into a sort of matting. Palm thatching seldom requires renewal oftener than once in three or four years, and then too it is only the upper layers that need replacement. Thatching composed of leaves of the *Wallichia densiflora* is extremely durable.

The leaves of other species, and also often of palms, are laid under or between grass thatch. By increasing the tightness of the roof, they enable it to be made extremely thin and light. Before the leaves can be used, they must be dried, after being pressed together and tied up in bundles. The leaves of teak and of *Bauhinia Vahlîi*, especially the former, are extensively so used and constitute an article of considerable export. Any broad fibrous leaf serves for thatching, and accordingly the leaves of many other species, such

as *Butea frondosa*, *Semecarpus Anacardium*, *Diospyros Melanoxyton*, &c., are often used in the vicinity of forests. Matting of palm leaves is often placed directly over the timbers of a roof before the grass thatch is put on and lasts for more than ten years.

#### SECTION V.—LEAVES FOR TANNING.

The leaves of a few species, such as *Anogeissus latifolia*, *Rhus Cotinus*, &c., are used in tanning. The leaves should be collected only when they are mature, but while they are still full of sap and before their colour changes previous to their being shed. The change of colour results from the appearance of colouring matters, which have their effect on the leather. Hence for white or light-coloured leathers there ought to be no delay in picking. The highest quality of leaves is obtained nearest the ends of the branches. After being picked, the leaves should be first wilted, then spread out and quickly dried, either in the sun or on racks arranged one above another in a heated room. To accelerate the process, the leaves should be frequently turned. Leaves properly dried should be greenish. For convenience of export, the leaves should be ground into a coarse meal.

The dried leaves of the various species of *Rhus* used for tanning contain 16—24 per cent. of gallo-tannic acid, and make a soft, pale-coloured leather. The leaves of *Anogeissus* give a similar leather, and the samples analysed by Professor Hümmel yielded 15½ per cent. of tannin, while those of the leaves of *Phyllanthus Emblica* gave as much as 18 per cent. The decoction of the leaves of both these species obtained by the Professor was of a pale yellow colour and slightly turbid.

#### SECTION VI.—SOME OTHER USES OF LEAVES.

The leaves of *Melaleuca Leucadendron* yield the Cajuput oil of commerce. The leaves of *Terminalia Catappa*, *Baccaurea sapida*, and some other species are used in dyeing, those of the first giving a black dye. The leaves of *Butea frondosa*, *Bauhinia Vahlüi*, and *Cordia Myxa* are very largely used by Hindus in the place of plates and cups. The plates are formed of several leaves pinned together with long spines or stiff grass stalks, while the cups consist of one or several leaves bent and pinned to the proper shape. The same leaves are also used by shopkeepers to wrap round grocery and other small articles that they sell. For these various purposes the leaves in question are exported to great distances. The leaves of the plantain are also used for plates. Both the leaves of the plan-

tain and of species of *Bauhinia* take the place of paper in the cigarettes smoked by the people of the Western Coast, while the leaves of *Cordia* are used to cover Burmese cheroots. The dried leaves of nim, *Vitex Negundo*, and some others are used as insectifuges. Pine needles, digested in a solution of caustic soda, yield more than 80 per cent. of their dry weight of a fine fibre (*pine wool*), which is made into felt and is woven into cloth resembling woolen fabrics.

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## CHAPTER V.—UTILIZATION OF MINOR PRODUCE OBTAINED FROM FELLED WOOD.

THE stem, besides yielding major produce, *viz.*, timber, firewood, and wood for charcoal, furnishes many other useful products that are extensively used. They may be grouped under the heads of (1) dyes and other extracts, (2) oils and the various products of distillation, and (3) starch.

### SECTION I.—DYES AND OTHER EXTRACTS.

The heart-wood of every species owes its colour to a substance or substances which can be used in dyeing; but these substances must be capable of being extracted with ease and in sufficient abundance to have a commercial value. In spite of the very slight knowledge possessed by our dyers of the various modes of manipulating dyeing substances, a great many dye woods are already used by them as well as by the general population. The Jack wood, *Plecosperrum spinosum*, and various others yield a yellow dye. *Pterocarpus santalinus* gives a very pretty salmon-pink dye, *Cæsalpinia Sappan* and *Adenantha pavonina* a red dye, *Cynometra ramiflora* a purple dye, and so on. But the most common colour yielded is some shade of brown. The easiest way to obtain the dye from wood that has been sawn is simply to boil the saw-dust. But for work on a commercial scale, the wood, before being boiled, would be most quickly reduced to thin shavings on a lathe.

The two best known and most widely used wood-extracts are the cutch and katha of commerce, the former being used principally as a dye and exported to Europe, the latter being chewed with betel and the betel leaf. From Upper Burma alone the annual exports, a few years before the annexation, amounted to 150,000 maunds, valued at Rs. 11,00,000. Since then, owing to restricted cuttings in consequence of reckless utilization during the late dynasty, they have diminished 50 per cent. in quantity and about 40 per cent. in value. In Lower Burma, in two Divisions alone (*viz.*, Tharawaddy and Prome), the annual revenue from cutch is not less than half a lakh of rupees. In India proper, the manufacture is on a much smaller scale; nevertheless the quantity carried by rail and river in 1888-89 was over 33,000 maunds, valued at

Rs. 5,00,000.\* Many of our dark-hearted trees, such as *Hardwickia binata*, *Soyimida febrifuga*, &c., would, no doubt, yield dyeing extracts quite as valuable as cutch. Industry and enterprise alone are wanting to bring them into use.

## SECTION II.—OILS AND OTHER PRODUCTS OF DISTILLATION.

The oils at present distilled from wood are those obtained from sandal-wood, from teak, from deodar, and from pines (chiefly *P. longifolia*, *Khasya*, and *Merkusii*).

Amongst these, the only articles of commerce are the produce of the sandal-wood, *Pinus longifolia*, and teak, the rest either having a very local use or being manufactured to meet an occasional demand.

The process of manufacture of sandal-wood oil will be described in Part III. A large quantity of wood is now wasted which would profitably be used for distilling the oil, and the establishment of stills in all the sandal-wood forests of Madras, Mysore, and Coorg would permit of those forests being worked and treated on a much more intensive system than can be adopted under present circumstances.

The oil of the deodar and *Pinus longifolia*, as well as of teak, is obtained by destructive distillation. The method of distillation is extremely primitive. Chips of the wood, long enough not to fall out, are put into an earthen pot with a narrow mouth. The chips are set on fire, and the pot is inverted into another, with a broad mouth. As the wood burns, the vapour of the oil condenses against the sides of the upper pot and the oil trickles down into the lower one. Sometimes the wood is not set on fire, but the two pots are so arranged that the inverted one is surrounded with fire. In either case, the produce obtained is never quite pure, as tarry matters and acids distil with the oil and discolour and taint it. This is, however, actually no disadvantage in the case of the conifer oils, which are at present used only for friction in rheumatism and skin diseases. Teak wood oil is rubbed into inferior woods to make them more durable and to give them the odour and oiliness of teak wood. In each one of these cases, tarry matters and a small quantity of acid probably add to the effectiveness of the oil. Teak wood oil, being siccative, is also sometimes used in the place of linseed oil.

The other products of distillation of wood, in which there is a trade, are acetic acid, wood-spirit, creosote, and tar. Of these, tar alone is made in this country, and that, too, only on a very small

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\* For further particulars regarding cutch and katha, see Part III.



scale for local consumption. The method of preparing wood-tar directly has already been described on page 147, and will again be further noticed in Chapter IV. of Part III. Although wood-tar can never compete with coal-tar in the general market, there is still plenty of room for its more extended use in and near the areas where deodar and pines grow.

The method of dry-distilling wood will be explained under the head of charcoal-burning in Part III. The acetic acid obtained directly from the distillation is full of various other products, and is in that condition termed pyroligneous acid. The pure acid is separated in the form of an acetate of lime, which is then heated with sulphuric acid, or, better still, hydrochloric acid, the base going to form sulphate or chloride, as the case may be, and setting free the acetic acid. Acetic acid is a powerful solvent of various organic bodies, camphor, resins, essential oils, phosphorus, &c. It is extensively used in the treatment of gums, caoutchouc, and various albuminous substances, in the manufacture of paints and varnishes, and as a drug. The uses of vinegar are well-known. The crude pyroligneous acid, owing to its containing creosote and other hydro-carbons, is a powerful antiseptic. Finally, acetic acid forms a series of salts, or "acetates," of special value in calico printing, dyeing, and other branches of industry.

Wood alcohol is, however, the most important product of the dry distillation of wood and constitutes about 1 per cent. of the distillate. Combined with sugar alcohol in the proportion of 10 parts to 90 of the latter, it becomes the methylated spirits of commerce, a product of such wide use in the arts and manufactures and in the scientific laboratory. Bleaching powder acting upon wood spirits produces chloroform. Ether is prepared by heating alcohol with sulphuric acid.

The products of the dry distillation of wood comprise, besides the substances already mentioned, all the substances, such as paraffin, benzene, &c., yielded in much larger quantities and at infinitely less expense by the distillation of coal.

### SECTION III.—STARCH.

The only woody Indian species from which starch is extracted are a few palms, such as *Caryota urens*, *Phœnix acaulis*, *Arenga*, and *Corypha*. This starch is, however, only consumed locally and has practically no market value. But there is no reason why it should not become an article of trade. Owing to the peculiar structure of the stems of palms, the centre consists entirely of cellular tissue rich in starch, the quantity of which is generally

largest towards the base, where the reserve materials are principally stored up. The starch is easily separated from the tissues containing it. These tissues are crushed and well rubbed and washed in water. The whole is then thrown upon a fine sieve, through which the starch passes with the water. The water is evaporated and only the starch remains.

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CHAPTER VI.—UTILIZATION OF MINOR PRODUCE  
FROM WOODY ROOTS.

THE roots of woody plants yield (a) food for man (*e.g.*, yams, *Pueraria tuberosa*, &c.); (b) drugs (*e.g.*, *Strychnos Nux-vomica*, *Hemidesmus indicus*, *Cissampelos Pareira*, mudar, some barberries, &c.); (c) fibres (*e.g.*, *Butea frondosa*, the aërial roots of some figs, &c.); (d) dyes (*e.g.*, chay or *Hedyotis umbellata*, known as Indian madder; *Rubia cordifolia*, yielding *manjit*, a product much resembling madder; *Morinda citrifolia*, yielding a scarlet dye, species of *Berberis*, a yellow dye, *Ventilago Maderaspatana* orange by itself, chocolate with chay, and black with galls; and so on). Many edible wild roots contain some acrid principle which can be got rid of only by long boiling. The fibres of the roots of the *Butea frondosa* are easily separated by beating the whole root with the back of an axe. These fibres, however, make only very coarse cordage, which becomes brittle in drying. Strips of the fresh-cut root are used for tying up thatch.

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## CHAPTER VII.—EXUDED PRODUCTS.

THESE are very numerous and of extreme importance. They may, for our purpose, be divided into (1) sugary sap, (2) gums, resins, and varnishes, and (3) rubbers.

## SECTION I.—SUGARY SAP.

The utilization of such sap is the basis of a very extensive industry. In India, the palms are the only family which contain trees that yield sugary sap. Those usually tapped are the coconut and palmyra palms, the *Caryota urens*, the *Arenga saccharifera*, the *Nipa fruticans*, and the wild date palm. The first four yield juice from the cut stalk of the inflorescence before the flowers appear, the last from incisions made in the stem at the base of the lower leaves, which are cut off. The sap, or toddy as it is called, of these palms flows in abundance. While it flows it is collected twice a day, the daily yield varying from a pint or two to several gallons. Nearly every spathe may be tapped, and the yield, therefore, depends on the number of spathes developed or cuts made. The same spathe or cut goes on giving toddy for nearly half the year; but periodically, about once, twice, or thrice a week, a thin piece has to be sliced off to freshen the wound. In the case of the wild date palm, the sides of the incision are freshened once a day for three days running each week, and the quantity of juice collected in the morning after each re-cutting is, in Bengal, respectively 16,  $6\frac{1}{2}$ , and 3 pints. During the three remaining days the outflow is insignificant, and the trees are allowed to rest before being cut again.

The toddy is largely drunk; but the greater portion is fermented and made into spirits and vinegar, or boiled down into raw sugar, which is refined at Cossipore in Bengal and in many places in the Madras Presidency. Toddy is nearly as rich in saccharine matters as cane juice, and as, unlike this latter, it is entirely free from colouring matters, chlorophyll and other impurities, the sugar it yields is much easier to clarify. The proportion of gur obtained

from date juice averages one-tenth by weight. The palm gur, as actually made, contains a large proportion of gluten, which causes it to deteriorate sooner than cane gur.

## SECTION II.—GUMS, RESINS, AND VARNISHES.

Gums are degradation products of the secondary cell-wall. The essential constituents of gums are *arabin*, *cerasin*, and *bassorin*, and according to which one of these three is present or preponderates, we have gum arabic, cherry gum, and gum tragacanth. Other constituents of gums are dextrin, sugar, tannin, colouring matters, and mineral ingredients. The various kinds of gum arabic, the type of which is obtained from several species of *Acacia*, are readily soluble in water at all temperatures and have the same composition as starch. They are the only gums which can be used for adhesive purposes. Cherry gum, to which category belong the exudations of *Bauhinia Vahlia* and *Thespesia populnea*, is insoluble in water, but absorbs it greedily and swells up into a transparent jelly-like mass. Boiled with a small quantity of some alkali, it is converted into gum arabic. Gum tragacanth, which is typically represented by the gum (*katira*) of the *Sterculias*, of *Cochlospermum Gossypium*, of *Eriodendron anfractuosum*, and of the cocoanut palm, is also insoluble in water, but, above a certain low minimum temperature, it absorbs water energetically, increasing enormously in bulk. It, however, becomes soluble when treated with an alkali. When acted upon by weak sulphuric acid, it yields a sugar that is incapable of fermentation. Most of our gums are mixed gums, that is to say, they contain two or all three of the three main constituents. Gums have various uses besides their employment as adhesive material. They are used in pharmacy as a medium for medicaments and as mucilage for soothing internal inflammation; also directly as a medicament itself. They are also largely employed in calico printing, in sizing paper, and in confectionery.

Resins are also degradation products of the cell membrane, but sometimes they are derived from fine-grained starch. In most species, the change into resin is brought about in those cells the vitality of which has been diminished from any cause. It is for this reason that resin is found in greatest abundance in the region of wounds, and that the stumps of felled pine and deodar trees become almost transparent with the large proportion of resin formed by the degradation of the cell-walls. Resins are soluble in

alcohol, ether, and carbon disulphide, but insoluble in water. They burn with a bright or a smoky flame.

Resins may be classified into (1) true resins, (2) gum-resins, and (3) oleo-resins. The true resins are (a) hard or copaline, as the resins of *Vateria indica* (pinèy), *Hopea odorata*, *Dipterocarpus tuberculatus*, *Shorea* spp., and *Canarium bengalense*, or (b) soft or *elemi*, as the exudation of *Boswellia thurifera*. The gum-resins embrace three sub-classes, (a) the emulsive (e.g., gamboge of *Garcinia Morella* and kino of *Pterocarpus Marsupium* and *Butea frondosa*), (b) the fetid (e.g., asafœtida and the exudations of *Gardenia lucida* and *gummifera*), and (c) the fragrant, this last being further sub-divided into two sections, represented respectively by the exudations of Balsamodendron (bdellium) and mango, and that of the genus *Styrax* (gum benjamin or benzoin). The oleo-resins embrace balsams (e.g., the gurjun "oil" of *Dipterocarpus turbinatus*, the wood "oil" of *D. laevis* and *D. zeylanicus*, and the copaiba-like balsam of *Hardwickia pinnata*), natural varnishes (e.g., the lacquers of *Melanorrhœa usitata*, *Rhus vernicifera*, *Semecarpus Anacardium* and *travancorica*, *Holigarna longifolia*), and turpentine and tars (the products of numerous conifers).

Gums are found in exploitable quantity only in the bark, while resins are formed in the wood as well as in the bark. In the bark the resin always occurs in special receptacles (resin cells or ducts); in the wood there may be special reservoirs, as in pines, or the resin may be secreted in the vessels themselves, as in the wood of the *Dipterocarpeæ*.

According to where the resin or gum is secreted, and to whether the secretion has or has not to be artificially aided, we have three modes of collection, *viz.*, (1) collection of spontaneous exudations, (2) collection from wounds made in the bark, and (3) collection by tapping the wood.

#### ARTICLE I.—COLLECTION OF SPONTANEOUS EXUDATIONS.

During the season of rest, especially when the bark becomes dry and cracks, and the tree, unable to transpire, is full of moisture, the low vitality of the numerous cells in the bark results in the formation of gum. It is also at this time that the outflow of resin is most active. The quantity of resin that bursts through the bark and exudes spontaneously is too insignificant to become an object of regular exploitation, and hence only gums are thus collected. Gums obtained in this manner comprise those furnished by *Anogeissus lati-*

*folia* and some of the Acacias, especially *A. arabica*. The yield of gum is largest after a forest fire, which not only reduces the vitality of the trees, but also enlarges existing cracks and creates new ones. The prolonged hot dry weather which precedes the setting in of the summer rains, however, suffices to produce a large quantity of the degradation product, chiefly in the more unhealthy trees; and we have thus a means, without setting fire to our forests and injuring growing timber, of deriving some sort of utility from trees, which, although they hold out no promise in respect of wood production, cannot, for some cultural reason or other, be removed.

#### ARTICLE 2.—COLLECTION FROM WOUNDS MADE IN THE BARK.

This mode of collection is employed chiefly in obtaining the kino of *Pterocarpus Marsupium* and *Butea frondosa*, the gum of *Bauhinia retusa* (sembla), and, in poor forests, also of *Anogeissus latifolia*, and the exudations of the Garcinias. In the case of all but the last, vertical rows of parallel, slightly oblique gashes, a few inches long and about 6 inches apart and penetrating as far as the wood, are made in the bark, all round the stem, and also round the main branches of small trees. The exudation collects generally in long or globular tears. It is allowed to harden on the wounds and is then broken or scraped off.

The sembla is subjected to a very systematic utilization. The trees are tapped twice in the year, *viz.*, during the dry seasons preceding respectively the summer and winter rains. The gashes are cut in March-April and September-October, and the gum collected in May-June and November-December. A rest of from one to two years after each year of exploitation suffices to enable the wounds to heal over and the trees to recover completely. According to Babu Karuna Nidhan Mukerji, the average yield per tree is about 5 seers of gum, which sells in the Dehra Dún bazar at an average rate of Rs. 3 per maund of 82 lbs. The sembla gum, like that of *Anogeissus*, is used in calico printing and is also eaten. The yield of kino from *Butea frondosa* is about the same as the yield of gum from the sembla, while that from *Pterocarpus* trees, which often attain an enormous size, is, no doubt, very much larger. The firs give resin only from the bark, but the yield is so small, that in the present state of the market it does not pay to tap those trees.

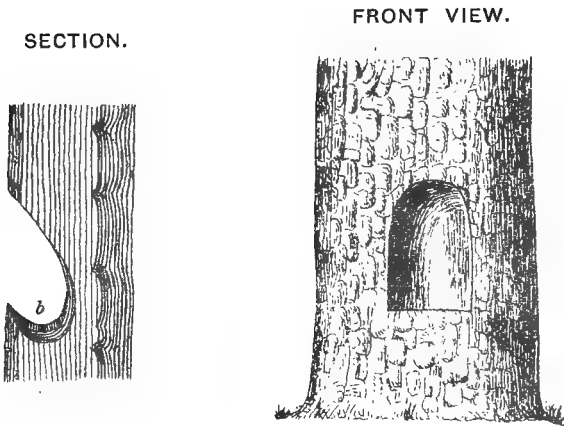
The true gamboge is not collected in India, although the tree which produces it, *Garcinia Morella*, grows in the forests of South India. In Ceylon the tree is tapped thus. Thin slices are cut off

the bark here and there. On the flat space thus exposed the gum collects and is scraped off when sufficiently dry.

### ARTICLE 3.—COLLECTION FROM WOUNDS IN THE WOOD.

This is the only mode of collecting the resins of the Dipterocarpeæ and of pines. The native method of tapping both families of trees is to cut one or more deep niches, according to the size of the tree, into the stem, at about 4 feet from the ground (Fig. 63). The height of the niche is about 18 inches and the

Fig. 63.



Niching *Pinus longifolia* for resin.

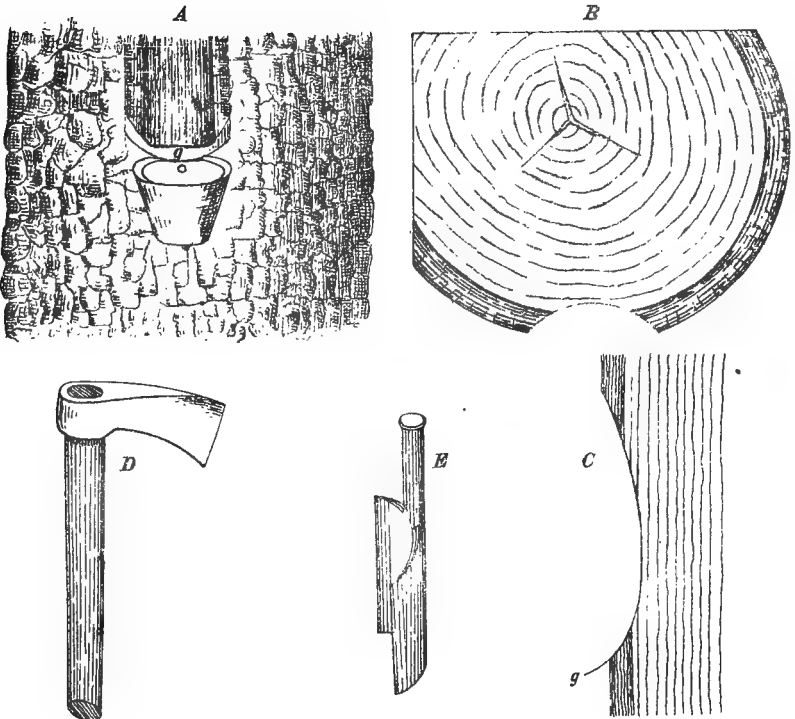
width at the opening about 1 foot. At the bottom it is hollowed out into the form of a deep bowl (*b* in Section) to receive the resin that runs down the sides. This hollow is emptied as fast as it fills up; in the case of *Pinus longifolia*, once in from 4 to 10 days when the niche is first made, and at longer intervals afterwards when the outflow diminishes. The Dipterocarpeæ are tapped during the dry hot months preceding the summer rains, *Pinus longifolia* during February-June, after which the resin, although it continues to flow, does not do so fast enough to tempt the collector to extend his work into the rains. In the pine a niche is worked for two and three consecutive seasons, unless a forest fire occurs and chars all the inside; and the yield is from 3 to 6 lbs. the first year, a little more than half that quantity the second year, and almost as much the third year. From time to time, however,



the resin encrusting the sides of the niche must be scraped off and the wound freshened. The method of tapping just described obviously injures the stem, and as the object of the tappers is to obtain the largest quantity of resin, the pines always suffer in their growth if they do not become sickly and die. It has been found that more than one niche in a tree up to 18 inches in diameter kills it. The open niche also allows bark and other impurities to fall into the turpentine.

Since 1887 systematic tapping operations have been carried on in the *Pinus longifolia* and *P. excelsa* forests in Jaonsar. An attempt has been made to follow the system employed in the tapping of the cluster pine in the west of France; but as the French curved-bladed axe (*Abchot*, Fig. 64 *D*) was found too

Fig. 64.



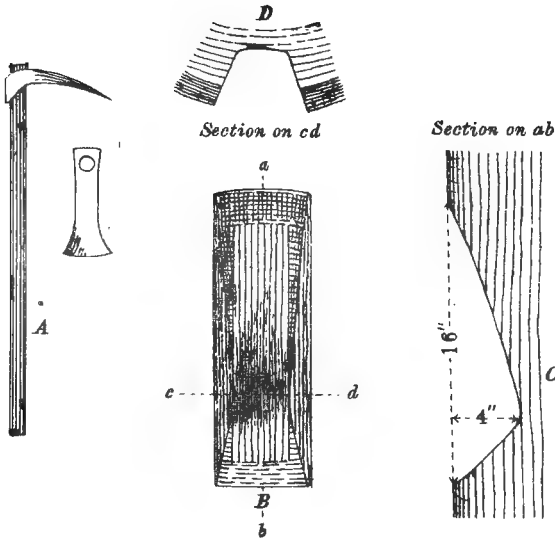
*French method of tapping pine for resin.*

*A.*—Blaze in full operation.  
*B.*—Blaze shown in horizontal section.  
*C.*—Blaze shown on a longitudinal section.

*D.*—Abchot or curved-bladed axe.  
*E.*—Curved chisel for making incision for admission of zinc gutter *g* in *A.*

heavy by the hill-men, the blaze has been made with the ordinary hill adze (*Fig. 65 A*). It would, however, be easy enough to

Fig. 65.



*Departmental method of tapping the Pinus longifolia in the Jaonsar Division, School Circle, N.-W. P. and Oudh.*

- A.*—Hill adze (weight under 2 lbs.)
- B.*—Blaze in elevation.
- C.*—Section on *a, b*.
- D.*—Section on *c, d*.

get lighter abchots made and the men would soon get into the way of using them. Regarding the superiority of the abchot to the adze there can be no question. It is more than twice as expeditious and effective, and for the same size of blaze injures the tree less, while the gently sloping edges of the blaze get more quickly covered over with the new deposits of wood (compare sections in *Figs. 64* and *65*). Then, again, in using the adze there is always risk of the tool working obliquely towards, and exposing the heartwood, and the sides of the blaze can never, from time to time, be freshened by the removal of a layer of wood, a mere fraction of an inch thick, as can be done with the abchot. *Fig. 64 D* represents a blaze in operation, with a zinc or galvanised iron gutter *g* fixed into the stem at the base of the blaze and a pot suspended immediately below, into which the resin drops from the gutter. The blaze, which has a nearly constant width of a little over 5 inches to begin with, should be made about 16 inches long.

In Jaonsar it is given a depth of 4 inches near its lower extremity (see *Fig. 65 C*). This depth is excessive, but it is impossible to make a shallower cut with the wretched adze used. The adze or abhot, whichever is employed, should always be almost as sharp as a razor, as a blunt edge, instead of cutting the resin ducts with a clean section, would bruise and lacerate the surrounding walls and thus choke up the entrance to the cavities. To preserve the edge of the tool, the dead, rough bark should be removed with an ordinary axe, and all old dry resin scraped off with a khurpa before using it. In Jaonsar the receiving pots were originally of iron, but they were so frequently stolen, that they are now made of ordinary baked clay, and are practically merely small flower-pots of about one imperial pint capacity.

As the gutter consists of only a thin flexible metal plate (*Fig. 64 A and C, g*), a groove is made to receive it with a curved chisel (*Fig. 64 E*). The metal plate is inserted into this groove and driven home with light blows.

Once a week, and even oftener when the resin flows very freely, the blaze must be freshened, as some of the exudation dries on the surface, thus clogging it and arresting the outflow of resin. In freshening the wound, a thin slice of wood, not more than the thickness of ordinary writing paper, should be taken off. At the same time that the blaze is freshened, it should be extended upwards a small fraction of an inch at a time, so that the blazes become generally longer with the advancing season.

Our experiments in Jaonsar have now gone on for three years, and there is still no point of any blaze either in *Pinus longifolia* or in *P. excelsa* from which resin is not still oozing out. In the niche system too, in the case of *P. longifolia*, the aggregate outflow during the second and third years exceeds that of the first year, and is very nearly as large in the third as in the second year. Such being the case, the extension of the blaze upwards should be effected very gradually, and when the length of any blaze becomes so great that the resin from the upper portion becomes too thick to run down freely until it reaches the gutter, a second gutter should be inserted about two feet above the first. The resin from this gutter may be allowed to drop directly on to the lower one, or a second pot may be hung on one side of the blaze and the gutter so shaped as to carry the resin sideways into it. It would not answer to suspend the second pot in a line with the blaze, for then the continued freshening of the blaze would become an impossibility, or would at any rate be extremely incommoded. If experience shows that it is desirable to extend the blazes to a

height of several yards, a series of such gutters and pots will have to be fixed one above another.

Experience both in Jaonsar and in the Punjab has proved that, although the flow of resin is most active during the season of rest and when the weather is warm and dry, it still continues to ooze out in fair, and sometimes in considerable abundance throughout the rest of the year. Pots left hanging in winter, under the snow, have been found to have overflowed with resin. It is, therefore, for consideration whether somewhat larger pots than those now used should not be tried, and due arrangements made for carrying on operations during the entire open season. Rainy weather is no drawback at all, for water being lighter than the resin cannot prevent the pots from filling with the latter. Large pots would also necessitate less frequent visits to each tree in order to collect the exudations, and one man could then look after more trees than he does now.

The blaze system of tapping, although it is only in an experimental stage, already promises to produce a larger outturn than the niche method. The two systems, carried out with chir trees situated in one and the same area, gave the following yield in the first year :—

Average per niche,	...	...	...	7·4 lbs.
„ „ blaze,	...	...	...	6·2 „

The niched trees were all large and specially selected, 20 in number, while the blazed trees numbered 3,221 and covered a whole hillside of about 200 acres only, so that many of them were quite small and not very vigorous. In the second and third years the niched trees gave respectively 4·9 and 4·5 lbs. per niche, whereas the corresponding figures for the blazed trees were 6 and 8 lbs.\* respectively per blaze. Even if the blaze system did not increase the yield, it at least saves the base of the stem from complete mutilation, and as it determines a flow of resin in the trunk uniformly in every direction, it will produce more highly resinous and therefore harder and more durable timber. Mr. Mann says that a single long blaze is often made in the trunk of Khasya pine trees one year before they are felled, with the object of increasing the amount of resin in the wood. The wood of trees so treated contains 16 per cent. of its total weight of resin.

A remarkable fact brought to light by the experiments in Jaonsar deserves to be mentioned. If a blaze goes through the sapwood of the *Pinus longifolia*, the exposed heartwood soon becomes full of cracks and dries up at the surface, and ultimately the flow of resin from the blaze is almost completely arrested. In the *Pinus*

\* The last figure is only approximate, as the exact quantity has not yet been communicated to the author.

*excelsa*, however, the outflow of resin apparently remains unaffected, even if a portion of the heartwood is removed in making the blaze.

Those of our conifers, the tapping of which is likely, in a near future, to become a large and profitable exploitation, comprise the three pines, *Khasya*, *Merkusii*, and *longifolia*, and perhaps also the *excelsa*. The aggregate areas covered by these pines are estimated respectively at roughly 200, 50, 2,000, and 100 square miles; but in these figures is probably included a large proportion of poorly stocked areas. The resin of the *Khasya* pine is the best, as it yields a purer oil than any other conifer resin in the world. The oil of *Pinus longifolia* is the least pure and has the least pleasant odour. It has also the great defect of not drying quickly—a characteristic which unfits it for the manufacture of varnishes. Excluding impurities, the turpentine consists of 18 per cent. oil and 82 per cent. colophony. The corresponding figures for *Pinus excelsa* are 22 and 78 respectively.

The utilization of the various turpentines will before long give rise to an important forest industry from the borders of Afghanistan to the frontier of Siam. A short account of the manufacturing processes through which the raw product passes will hence be given in Part III.

### SECTION III.—CAOUTCHOUC AND ITS ALLIES.

These substances are found suspended, in the form of small granules, in the latex of numerous plants belonging principally to the *Euphorbiaceæ*, *Apocynaceæ*, *Asclepiadaceæ*, *Sapotaceæ*, *Lobeliaceæ*, and *Urticaceæ*. The latex, after a shorter or longer exposure to the air, becomes coloured brown, and the granules separate of themselves from the rest of the liquid and form a solid independent mass. Caoutchouc is insoluble in water, acids, alkalies, and alcohol; soluble, but without any chemical change, in carbon disulphide. Its composition is complex, but its market value depends upon a proportionate abundance of the elastic substance, with a relative absence of a certain oxidized, viscid, resinous body soluble in alcohol, whose formation is in great measure prevented by rapid evaporation of the milk and other means of avoiding oxidation.

In India the only species tapped on a large scale for caoutchouc is the *Ficus elastica*. In Burma *Parameria glandulifera* is said to yield a product equal to the best Para rubber, and *Urceola esculenta* is described as very abundant, but not yielding as good a rubber. Both are Apocynaceous climbers. They are not tapped, but cut down, and the bark is at once stripped off and boiled. The hot water, however, causes much of the milk to coagulate inside the bark and thus reduces the yield very considerably.

The *Ficus elastica* throws out numerous large aërial roots, some of which run for many feet along the ground. Both the stem and these roots are tapped, the latter being more productive. February-March is considered the best time for tapping. Oblique incisions, about 3 inches wide across the middle, are made right through the bark. The exudations, if abundant, are received in conical cups made of folded leaves (pots would surely be more convenient and effective); otherwise they are allowed to concrete on the wound. Native collectors often allow the milk to run down into holes made in the soil. The incisions used to be made only 1 foot apart, but this was found to weaken the trees. In the State forests an interval of 2 feet is now adopted, and in tapping the same trees again, the new incisions are made between the old ones; if these latter are opened again, not only do the trees suffer in vigour, but the yield of milk is diminished 50 per cent. If the milk is left to itself, it solidifies in about 20 days, when it is stripped off the wounds or taken out of the leaf-cups or holes in the ground, and kneaded into a ball, whence the designation of *ball rubber* for this product. *Leaf* or *slab* rubber is thus prepared. The fresh milk, collected within 24 hours after incision, is poured into boiling water, and the mixture is briskly agitated until the rubber separates and can be handled without sticking and kneaded. A more elaborate plan is to run the milk into wooden bins partially filled with water, on which the rubber begins to float after a time. The rubber, while still liquid, is removed and boiled over a slow fire in iron pans 4 to 6 feet in diameter and  $2\frac{1}{2}$  feet deep, two parts of water being added and the whole stirred constantly. When coagulated, the rubber is removed with iron forks, pressed, again boiled and pressed, sun-dried, and washed over with lime.

The average yield of rubber is one-third the weight of the semi-liquid latex. Ball rubber is obviously more impure than loaf rubber (the impurities often reaching 35 per cent). Owing to longer exposure to oxidation, while coagulating naturally, it also gives a smaller yield. Even when loaf rubber is made, a certain quantity of the ball kind is obtained from what collects subsequently and solidifies in the wounds. The ball rubber, when just pulled off the tree, contains about 17 per cent. of moisture, which, however, it soon loses after being rolled up and sunned.

The yield of course varies very much with the size and age of the trees and the number of aërial roots, and with the weather. Unseasonable rain may wash away almost all the latex. Middle-aged trees are the most productive. Large healthy trees have been known to yield as much as 150 to 200 lbs.; but the average yield,

in the present condition of the forests and plantations, is only about 10 lbs. per tree.

The trees require at least one year's rest between two tappings, otherwise they decline in health and may even die. Gamble recommends a rest of two years.

The total exports of India-rubber from and through Assam amounted, in round numbers, to 7,500 lbs. in 1887-88, of which 1,000 lbs. came from Bhutan and other tracts inhabited by hill tribes. The price of the rubber at Calcutta fluctuates considerably, but the average may be taken at Rs. 80 per maund, or very nearly Re. 1 per lb.

Gutta-percha is closely related to caoutchouc. The tree that yields the gutta-percha of commerce, *Dichopsis Gutta* (one of the Sapotaceæ) is not a native of India; but one Indian species, *D. polyantha*, yields a very good article, quite capable of exploitation. Mr. B. F. DaCosta claims to have discovered in the latex of *Euphorbia nerifolia* a substance having the properties of gutta-percha and capable of being substituted for it.

## CHAPTER VIII.—UTILIZATION OF ANIMAL PRODUCTS.

THE most important of these are lac and lac dye ; silk ; honey, wax, and manna ; and hides, horns, bones, and ivory. Under this head may also be included hunting and fishing.

### SECTION I.—LAC AND LAC DYE.

The lac insect (*Coccus Lacca*) frequents a great many species of trees and shrubs, but of these *Schleichera trijuga*, *Butea frondosa*, *Zizyphus Jujuba*, and *Shorea laccifera* are alone gregarious enough to be regularly exploited for lac without resort to artificially-raised plantations.\*

The lac insect breeds twice, and, in Mysore, even three times a year, but the spring brood yields the largest quantity of lac. As the insect can survive and form thick incrustations only on twigs of generous growth, the trees on which it is cultivated should always be pruned and lopped, in order to induce an abundant crop of strong juicy shoots. In the case of *Butea frondosa*, it will doubtless be best to adopt pollarding outright.

To cause the insect to spread over the whole tree or bush, the brood lac, as it is called, which is nothing more than fresh-broken lac from which the young insect has not yet swarmed out, is cut up into short pieces 6 to 12 inches long and tied up at various points in the crown, after being surrounded with a few wisps of straw in order to protect the young brood inside from injurious weather in-

\* Besides the above, the following trees and shrubs are frequented by the lac insect :—

<i>Acacia arabica</i> and <i>Catechu</i> .	}	<i>Garuga pinnata</i> .
<i>Anona squamosa</i> .		<i>Kydia calycina</i> .
<i>Butea frondosa</i> and <i>superba</i> .		<i>Lagerstrœmia parviflora</i> .
<i>Carissa Carandas</i> .		<i>Mangifera indica</i> .
<i>Celtis Roxburghii</i> .		<i>Nephelium Litchi</i> .
<i>Croton lacciferus</i> .		<i>Ougeinia dalbergioides</i> .
<i>Dalbergia latifolia</i> and <i>paniculata</i> .		<i>Pithecolobium dulce</i> .
<i>Dichrostachys cinerea</i> .		<i>Prosopis spicigera</i> .
<i>Dolichandrone Rheedii</i> .		<i>Pterocarpus Marsupium</i> .
<i>Eriolana Hookeriana</i> .		<i>Schima crenata</i> .
<i>Erythrina indica</i> .		<i>Shorea robusta</i> .
<i>Feronia Elephantum</i> .		<i>Tectona grandis</i> .
<i>Ficus bengalensis</i> , <i>cordifolia</i> , <i>elastica</i> , <i>glomerata</i> , and <i>infectoria</i> .		<i>Terminalia tomentosa</i> .
		<i>Zizyphus xylopyra</i> .



fluences and to create numerous points of contact with the branch to enable the larvæ to pass over at once. The pieces should be tied up in the upper and middle branches, so that any wandering larvæ that may fall off from them may not be lost on the ground, but find a lodgment on the lower branches immediately underneath.

The brood lac may be gathered without any danger a whole fortnight before the young larvæ swarm out, so that there is always time enough to plant them on any number of trees.

The wood of the tree on which the brood lac is to be tied should not be harder than the wood of the tree from which it has been taken off; otherwise the larvæ may not be sufficiently powerful to draw nourishment from the new host. On the other hand, brood lac from harder-wooded trees may generally be safely propagated on a softer-wooded one.

As soon as the larvæ issue forth from the lac, they crowd over the whole crown, attaching themselves to wherever the bark is soft and juicy enough and soon covering the entire length of the twig with their incrustations. The male larvæ swarm out, attach themselves to the host, and begin to form incrustations round themselves exactly like the female larvæ. But when they become mature, they leave their cells to impregnate the females, now also mature. This exit of the perfect males must not be mistaken for the swarming of a young brood; lac broken off at this stage would be utterly worthless both for propagation and for sale.

The lac insect is extremely sensitive to low temperatures and to dry heat. It has also many enemies. Ants invade lac-bearing trees in numbers for the sweet excretions. They bite off the ends of the white filaments and thus prevent a sufficient supply of air from reaching the insects; but they are easily kept off by surrounding the foot of each tree with wood-ashes or by tempting them with other more attractive food. Monkeys also break off and chew the incrustations for the same sweet substance and injure more than they can eat. The larva of a moth (*Galeria*?) bores through the cells, devouring the juicy females. A *Tinea* also works its way into the cells and eats the colouring matter. No mode of protection has yet been devised against these two last pests.

What is not required for propagation is sold. This lac also is gathered before the young brood can make its appearance and exhaust the dye. In this unprepared condition the lac is technically called *stick lac*. To obtain the dye, the stick-lac is passed under a roller in order to detach the incrustation from the wood which it surrounds. The small portion still remaining is picked off with the hand. The separated lac is then crushed and washed

in water, which effectually removes all the dye. The water is strained and the dye allowed to settle, precipitation being assisted by an admixture of alum or lime. The water is drawn off and the sediment collected, pressed into cakes, and dried in the sun. Cotton wool is often saturated with the dye and used by confectioners for colouring sweetmeats, and by women for rouging their hands, feet, and faces. Since the introduction of aniline dyes, the demand for lac dye has become insignificant.

The resinous portion or real lac (in this condition termed *seed lac*) is dried and placed in a long bag of fairly close-woven cotton drill. The bag is held by two operators over an open charcoal fire, which melts the lac inside. The men, one at each end, now begin to twist the bag in opposite directions, so that the melted lac is forced through the cloth and drops into a long trough underneath. From this trough, which is hot enough to maintain the lac in a molten condition, a third operator throws a ladleful on to a smooth hollow cylinder of porcelain or metal filled with warm water. Without any delay a fourth operator quickly spreads the lac evenly over the cylinder with an aloe or plantain leaf. The sheet of lac is at once lifted off, and waved about in the air for a moment or two until it is quite crisp. This is the *shellac* of commerce. The cylinder is kept warm to prevent any portion of the lac adhering to it. In Bengal, the shellac is often solidified on plantain stems. If, instead of using the cylinder, the melted lac is dropped upon a smooth plane and assumes the shape of small ginger nuts, it becomes *button lac*, which generally commands higher prices in the London market than shellac.

*Schleichera trijuga* furnishes the most valuable product, a bright amber-coloured lac. The lac of *Butea* is reddish.

The total inland trade in lac in India proper carried by rail and river in 1888-89 was composed as follows :—

Stick lac, ..	200,000	maunds,	worth	36	lakhs	of	rupees.
Shellac, ..	125,000	„	„	65	„	„	„

In India lac is used in the manufacture of bangles, lacquer ware, varnishes, and sealing wax ; in Europe for the preparation of spirit varnishes, cements, lithographic ink, and sealing wax, and for the stiffening of hats.

## SECTION II.—SILK.

Perhaps no country in the world is so rich in indigenous silk-producing insects as India, the number of species exceeding thirty. They are divided by F. Moore into—

I.—THE MULBERRY-FEEDING GROUP, represented by the various

domestic Bombyces and by the wild *Theophila*. *Theophila Huttoni* is abundant in the North-West Himalayas, but Mr. Cotes says: "It has not been found possible to rear the worms successfully in captivity, and the silk is not made use of commercially at present. The worm is bivoltine in Mussoorie." The name of the group is misleading, as several species feed on other Urticaceous plants: thus *T. religiosa*, the *jori* of Assam and *deo-mooga* of Cachar, lives on *Ficus bengalensis* and *religiosa*.

II.—THE ATLAS OR ERI GROUP, comprising the genus *Attacus*. *A. Atlas* is found in many parts of the empire feeding on a variety of trees. It is not cultivated, but its silk, when procurable, is highly prized. The eri silk, possessing little lustre and not capable of being reeled, but extremely durable when woven, is produced by *A. Ricini*, which is entirely domesticated.

III.—THE ACTIAS GROUP.—*A. Selene* is found in many parts of India on *Pieris ovalifolia*, *Coriara nepalensis*, cherry, walnut, *Odina Wodier*, &c. Mr. Cotes says that no use is made of its silk.

IV.—THE TUSSER AND MOOGA GROUP, comprising the large genus *Antheraea*. The two most important species, and indeed the most important of the wild silk-producing moths of India, are the *tusser* (*A. Mylitta*) and the *mooga* (*A. Assama*). The former is bivoltine, the latter multivoltine, the first and last crops being most productive as well as of the highest quality. Both are largely reared in the open air, the tusser chiefly in the Central Provinces and in Chhota Nagpur on various trees, the principal of which are *Terminalia tomentosa* and *Arjuna*, *Lagerstrœmia indica*, *Carissa Carandas*, and *Zizyphus Jujuba*, the mooga in Assam on *Machilus odoratissima* and *Tetranthera monopetala*. The trees have to be pollarded both for convenience and to produce a good crop of leaves. 24 lbs. of mooga silk per acre, valued at Rs. 110 to 130, is a good outturn. The expense of rearing is trifling. The cocoons of both the tusser and mooga worms can be reeled and yield a valuable silk, that of the former being remarkable for its strength and durability and consisting of tape-like, not the usually cylindrical, filaments.

V.—A MISCELLANEOUS GROUP, including *Rhodia Newera*, found in Sikkim and Nepal, and *Cricula trifenestrata*, or the mango silk-worm, distributed in most parts of the empire. The silk of the former is not used, while that of the latter cannot be reeled and is not of much value.

The Inland Trade Returns for 1888-89 for India proper show a trade in home-produced raw silk valued at nearly 2 crores of rupees. The trade in silk fabrics, independently of a large local consumption, showed the figure of 60 lakhs.

## SECTION III.—HONEY, WAX, AND MANNA.

Honey and wax can, for the forester, be only natural products; but, thanks to the teeming numbers and extensive distribution of our wild honey-making bees, they are obtainable in very large quantities, especially where rocky scarps and large trees abound. The combs are often as much as 6 feet long and  $3\frac{1}{2}$  feet broad. The usual mode of collecting the honey is to smoke off the bees, the men covering themselves with blankets and carrying a torch at the end of a pole. This practice injures the honey; but there are some tribes which possess the secret of anointing their bodies with some substance, so that not a single bee will touch them. The honey is obtained by expression. The remains of the comb are then put into boiling water, the wax soon floating on the top, where it hardens on the water being cooled. In this state the wax is known as yellow or virgin wax. The best honey in India is made by a species of *Trigona*, which is a small stingless bee building its comb inside hollow trees.

Manna or honey-dew is the sweet substance excreted chiefly by some Aphidæ. In certain, especially dry, years, these insects breed in enormous numbers, so that every tree of the species on which they live becomes infested with hundreds of thousands of them. The total amount of sweet substance excreted is then so large, that the leaves and twigs become covered with a thick syrup, much of which also falls upon the ground. The species frequented by such insects are principally gregarious conifers and only a few broad-leaved species, such as *Elæodendron glaucum* and *sál*.

Honey-dew is eagerly gathered, for home consumption, by the inhabitants of the Himalayas. The encrustation is washed off the leaves and twigs in hot water, which dissolves it at once. The syrup is then strained and boiled down to the consistence of honey, for which it may be easily mistaken by its appearance. A considerable proportion of the honey-dew crystallises at ordinary temperatures.

## SECTION IV.—HIDES, HORNS, BONES, AND IVORY.

Every year thousands of cattle die inside our forests, the carcasses remaining unappropriated by the Hindu owners. Unless arrangements are made to secure the hides without delay, carrion-eating birds and quadrupeds soon destroy them and valuable raw material is thus lost. Excluding Burma, the inland trade during 1888-89 in raw hides amounted to 75 lakhs of rupees and in

leather to 83 lakhs. These figures leave out all local consumption, which is worth many times more, since every village has its tanners and nearly every village its shoemaker. In the same year Calcutta alone exported to inland places 30 lakhs' worth of leather goods.

The horns of the dead cattle, especially if they are buffaloes, are also worth collecting. There are, at present, practically no workers in horns in India, but there is a large export trade in them to Europe (about 65,000 maunds, of an aggregate value of 9 lakhs of rupees), and the day cannot be far distant when combs and other articles will be extensively manufactured from horns in India itself, instead of the raw article being sent out of the country or allowed to perish in the forests and on the outskirts of towns and villages.

The so-called horns of deer contain no horny matter at all, but consist entirely of bone and really constitute an inferior kind of ivory. A small quantity of deer horns that have been shed can be collected in almost every forest and would command ready sale. As regards ivory, since the number of elephants is kept down by the kheddah operations, and elephants live to a great age, the annual find will always be insignificant and irregular.

Bones are used for buttons, handles of knives, &c., and are also ground into meal for manure. A large export trade to England in bone-meal has recently sprung up from Bombay and Kurrachee and along the routes leading to those ports. The total exports from the country amount to about 50,000 tons a year. The price of the meal in Bombay is Rs. 35 to 45 per maund. As yet the Indian ryot is too prejudiced to use bone manure, but before long the prejudice will disappear, and then every scrap of bone lying in the forest will become marketable.

The best way to dispose of the products grouped under this head is to give out annual leases for their collection, but great care must be taken that the animals are not poisoned or shot by the lessees.

#### SECTION V.—HUNTING AND FISHING.

In all advanced countries a considerable income is derived by the owners of forests and streams from hunting (including snaring and trapping) and fishing; and, where dangerous animals abound, special arrangements are maintained by the State for their destruction. Two principal causes have hitherto militated in India against the introduction of laws to regulate hunting and fishing: (1) the

great abundance of game and fish in comparison with the wants of the apathetic population, and (2) the unwillingness of an important section of the community to submit to restrictions in the matter of sport. An excellent beginning has, however, now been made in the Central Provinces and Madras, close seasons have been declared for certain descriptions of game in most provinces as far as the State forests are concerned, and numerous municipalities treat some kinds of dead game as contraband during the breeding season. Fire-conservancy has also operated in the preservation of game and fish by closing the conserved forests during nearly half the year, and thus affording game a safe retreat and protecting the higher reaches of rivers from molestation. Circumstances are thus ripe for extended imperial legislation, which cannot be undertaken too early, and which the Supreme Government have already under their earnest consideration.

In regulating hunting the following general points, amongst numerous others of a more special or local character, must be kept in view :—

(1). Separate rules must be made for animals dangerous to man and cattle. If such animals cannot be exterminated, their numbers must be kept down as low as possible; hence special facilities should be given for their destruction, and rules must be relaxed and large discretionary powers given to the superior local officials in the case of rogue elephants and man-eating *Felidæ* and *Canidæ*. Where dangerous animals abound, the District Magistrate or Divisional Forest Officer may surely be empowered to organize and conduct annual expeditions for their destruction, a reasonable budget grant being allowed for necessary expenses. Forest conservancy, by affording increased cover and protection and a larger supply of food, favour in a remarkable manner the multiplication of elephants and beasts of prey. The rewards offered for killing dangerous animals must be adjusted to the urgency of their destruction: a single tariff for an entire province and sometimes even an entire district is a mistake. Solitary wild boars not unfrequently become dangerous enough to require being specially marked down for destruction.

(2). All vegetable-feeding mammalia are harmful to field crops as well as to forest growth.\* Pigs will break through almost any

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\* Elephants are under the protection of a special Act, and the Forest Department can only suggest their being caught when they have become numerous enough for a kheddah.

fence, and deer and antelope will clear most obstacles that can be put up to stop them. Limitation of their numbers is, therefore, in the interests of all. Their total annihilation would be a mistake, for by their presence the ravages of the large beasts of prey amongst men and live-stock are restricted, and they supply a large part of the population with meat, and provide an innocent and absorbing pastime, than which nothing better can be conceived for developing sense of locality, powers of observation, capacity for endurance, fertility of resource, self-control, and promptitude of judgment. Moreover, the right of hunting them may be sold for a sum of money large enough to more than cover the risks arising from their preservation. In the case of deer and antelope no hunting should be allowed during rutting time, and the killing of females should be forbidden during the entire breeding season, which extends roughly from 1st July of one year to 1st March of the following year. After a careful study of the habits of the animals and the capacity of the forests to yield them food without suffering real harm, the number of full-grown males and females to be preserved in each forest should be fixed, all above this number being considered legitimate quarry.\* If the actual numbers are under this minimum, no hunting should be permitted until its figure has been reached. In the case of forests bordered by extensive cultivation, the safety of the fields must also be considered in fixing the head of game to be maintained ; but their ravages will usually be found confined to a very narrow belt of cultivation, and the owners of fields lying within this belt will in any case find their compensation in a lower assessment of land revenue. As regards pigs, they are so prolific that, in the present condition of the country, their numbers can seldom be kept down without the help of one or more large battues a year, in which every neighbouring villager should be invited to join. The organisation of such battues will cost no money, as most people will be only too glad to get meat free and enjoy the pleasure of the sport, and every one will do his best to get rid of a pest that ravages his crops.

(3). The destruction of birds other than game and edible birds should be forbidden, and for these latter a close season should be observed, long enough to allow the young to be sufficiently grown to take care of themselves. The Central Provinces Government, acting on the advice of that accomplished sportsman and naturalist, Mr. R. Thompson, has adopted the following limits for the various game and edible birds :—

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\* This may sound unsportsmanlike, but our concern is with the good of the country—forestry first, sport afterwards.

1.	Sand grouse, ...	... 1st October to 31st May.
2.	Pea-fowl, ...	... 1st March to 30th November.
3.	Jungle fowl, ...	... " " " "
4.	Spur-fowl, ...	... " " " "
5.	{ Partridge, grey and painted,	1st June to 30th November.
	{ " black,	... 1st January to 30th November.
6.	Quail, ...	... 1st May to 30th November.
7.	Bush-quail, ...	... " " " "
8.	Bustard-quail,...	... " " " "
9.	Bustard, ...	... " " " "
10.	Lik-florikan, ...	... " " " "
11.	Spurred goose,	... 1st June to 30th November.
12.	Goose-teal, ...	... " " " "
13.	Whistling teal,	... " " " "
14.	Grey duck, ...	... " " " "
15.	Green pigeon,	... 1st February to 31st July.
16.	Blue rock-pigeon,	... 1st November to 30th June.
17.	Doves, ...	... 1st November to 31st May, but for <i>Turtur senegalensis</i> , 1st February to 31st July.

Most birds are the forester's friends, and should, therefore, be carefully protected by him.

(4). The practice of snaring of birds in the vicinity of large centres of population should be discouraged or even put down as much as possible.

(5). For the destruction of a proclaimed animal, such as a man-eating tiger, rogue elephant, &c., three lines of action offer themselves. Either the local officials may organize an expedition, or a single individual or party may receive exclusive permission to hunt it, or numerous parties acting independently of each other may be allowed to pursue it. The first system is obviously the most likely to succeed, and exposes the forest to the fewest risks. Failing it, the second system is to be preferred, but the forest officer must assure himself that the individual or party commands all the necessary resources for success.

(6). For the destruction of ordinary game, the right to hunt in a specified locality may be leased to a single party, or all may be allowed to come who obtain a permit to hunt. The country is at present not advanced enough for the general adoption of the former alternative, which is without doubt the one to strive for, as it fixes responsibility, and the wealth and position of the single lessee are a guarantee of his good faith. In adopting the other alternative a reasonable fee should, whenever possible, be charged as the price of the permit. The amount of the fee should be re-



gulated principally by the value of game in the locality, the accessibility of the forest, and the number of applicants. If it is desired to limit the number of applicants, high fees should be charged. The fee may be fixed for the whole year, or the year may be divided into periods, the scale of fees for the several periods being proportionate to the dangerous nature of the season for forest conservancy and the convenience of the time of the year for seeing and tracking game. The levy of the fees should be based on the number of "effective guns" with the party, *i.e.*, the number of persons carrying and using guns. The number of elephants used in hunting should also be taken into account, and a certain fee charged for each such elephant. All other things being the same, the success of a hunt will depend on the number of elephants used, and sportsmen possessing the means to employ elephants are *ipso facto* able to pay higher fees than other people. Moreover, elephants crush and break a good deal of the forest growth, besides grazing as they are driven along. On the other hand, sportsmen mounted on elephants have less temptation to fire the grass, and are more to be trusted than the majority of those who cannot afford the use of elephants. The fees should in any case be high enough to leave a reasonable surplus after paying for additional establishments required by the increased supervision necessary for controlling the hunting. Every large hunting party should be accompanied by a trustworthy official, whose special duty will be to look after the followers and prevent acts endangering the safety of the forest, particularly when the party is encamped inside the forest.

Fishing is very much more easily regulated than hunting. It involves but little, if any, risk to the forest, and is limited to definite lines, and may often even be restricted to certain lengths of the course of a stream or to pools and tanks. Hence the sole object to be sought in prescribing rules for fishing is the preservation of the fish, and to this end the poisoning or damming up of water should be absolutely prohibited and a minimum size of mesh should be fixed for fishing nets. A close season may also be prescribed for fishing generally in special spawning grounds or for particular kinds of fish everywhere. For purposes of revenue, the right of fishing may be leased or a certain fee may be levied per net or rod. In the rains, when the rivers are in flood, the water-courses that are at other seasons dry become rapid torrents, and fish come up them in shoals and are easily clubbed. From people who thus club fish and from those who catch fish by torchlight from under stones and boulders it will always be difficult to collect revenue. The latter practice should, however, in most cases be forbidden.

## CHAPTER IX.—MINERALS.

NUMEROUS mineral products are obtained from forest areas. The principal of these are building stones, which may be either for cut-stone or for rubble (including boulder) masonry ; flagging and paving stones ; slates ; metal for macadamised roads ; gravel and sand ; lime-stone for mortar and plaster ; gypsum, kaolin and potter's clay ; talc and mica ; coloured clays for plastering and dyeing ; peat and lignite ; ores ; and gold ; and so on. These various materials may be obtained either (1) by quarrying, or (2) by cutting down or breaking up a hillside, or (3) by collecting off the surface of land producing or capable of producing forest, or (4) by gathering from stream beds. The second of these methods is an extremely destructive one, unless the portion of the hill to be cut away is judiciously chosen and is of limited extent, and the stones removed are not allowed to be rolled down the hillside. The danger is greatest in loose sandstone and metamorphic formations, especially when only particular strata are exploited, in which case the removal of these strata necessarily undermines those overlying them. Unless precautions are rigidly enforced, any kind of vegetation on the hillside will become impossible and the safety of the hillside itself will be threatened. The third method, which is very commonly resorted to in broken country of trap and sandstone formation, is always harmful. As the stones lie about everywhere, their collection and removal to central export depôts result in much damage to forest growth of all ages. Quarrying into the earth is much less dangerous than the two methods just referred to ; but unless regular metalled roads or tramways are made to the quarry, the constant going to and fro of heavily laden carts will do damage to a large extent of surrounding forest. The least dangerous of all the four methods is collection from the beds of streams ; the materials being taken in small quantities from a great many points all along the course of the stream, there is never any dangerous concentration of traffic.

If kankar or any other limestone is used, burning it on the spot secures economy both of fuel and carriage. The kilns should be constructed only on open sites some distance from good forest growth. The most convenient mode of levying payment, when

the utilization is on a large scale, is to lump up the price of the firewood and stone together and to charge a fixed rate for one burning, according to the capacity of the kiln. By this means the worry and labour of frequent measurements and of watching against unpaid removal, as well as all chance of disputes, are effectually avoided, and no premium is offered on careless or unskilful burning. In the dry shallow beds of streams issuing from the Himalayas, numerous pebbles and boulders of limestone are annually brought down by the floods during the heavy rains. They are collected without trouble, and yield excellent lime, which is much in request. This limestone is best sold by leasing for a lump sum, for a whole year or season, definite lengths of the stream course, and then the price of the fuel should be separately recovered at so much a charge according to the capacity of the kiln.

The exploitation of ores will nearly always be effected on the same basis as that of limestone. Iron-smelting, on a small scale and according to most primitive methods, is carried on in many of our forests.

In several of our rivers washings of the sand yield a small quantity of gold. As it is impossible to check the quantity collected, each collector should be made to pay a certain fee per month or season, according to the richness of the sands.

Stones for building, paving and road-material, and other minerals are best sold by measurement, although exceptional cases may occur in which the levy of a fixed rent will be found preferable.

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## PART III.

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### MINOR FOREST INDUSTRIES.

THE only minor forest industries that will be dealt with in this Part are—

- I.—Charcoal-burning.
- II.—Manufacture of cutch and kattha.
- III.—Distillation of sandal-wood oil.
- IV.—Preparation of turpentine products.
- V.—Impregnation of timber with antiseptic substances.

Several petty industries have already been briefly described in Parts I. and II.; as, for instance, the manufacture of tar at page 69, the distillation of teak and deodar oil at page 170, and so on. In the course of a few years the number and extent of such minor forest industries in this country are certain to undergo an enormous expansion, requiring the employment of hundreds of thousands of the population.

#### CHAPTER I.—CHARCOAL-MAKING.

If wood is burnt with free access of air, there will be nothing left of it but a small quantity of ash varying, for most of our species, from  $\frac{1}{2}$  to 2 per cent. of its dry weight. If, on the other hand, air be entirely excluded and the wood subjected to a temperature of  $300^{\circ}$  to  $350^{\circ}$  C., a number of liquid and gaseous products will be given off, what remains behind being charcoal. Charcoal-making, or the carbonisation of wood, is thus only a process of destructive distillation. In this process all the moisture, most of the oxygen and hydrogen of the wood, and about half the carbon are expelled, so that the charcoal consists of the remaining carbon, oxygen and hydrogen, and all the ash elements, the carbon constituting about 90 per cent. of the whole. Actually the charcoal-burner uses wood with its bark on, the result being a somewhat larger proportion than 10 per cent. of elements other than carbon.

As just said, more than half the aggregate quantity of the combustible elements, *viz.*, carbon, oxygen, and hydrogen, is lost in carbonisation. But, on the other hand, the advantages gained are

numerous and important. In the first place, the heating power of charcoal is very nearly twice that of the same weight of wood, being just a little inferior to that of English coal and superior to that of Indian coal. In the second place, charcoal is easier to light and maintain burning than wood, and gives out a very much more steady heat. In the third place, charcoal makes a clear, smokeless fire, and on this account is preferable, for metallurgical purposes, to coal in the production of the finer varieties of iron and steel. In the fourth place, it is always ready for immediate use, whereas wood has to be cut or split up to convenient sizes. In the fifth and last place, in addition to being so very much more effective and convenient a fuel, it is less than a quarter of the weight of the original wood and less than half the bulk, so that it can stand very much longer carriage (at least three times as long) than wood, and thus enables us to utilise the small produce of distant forests that would otherwise be quite unsaleable and have to be left behind in the forest to feed forest fires, favour the unchecked multiplication of destructive insects and fungi, and impose a forced limit on the improvement of the stock.

There are numerous methods of making charcoal, but they may all be reduced to three main systems, according to the care taken to exclude air. These three systems are (1) carbonisation in retorts and close ovens, (2) carbonisation in ordinary kilns, and (3) carbonisation in open pits.

Whichever method is adopted, it is necessary that all the wood in process of carbonisation should be converted into charcoal as nearly as possible simultaneously; otherwise those pieces which were carbonised first would become partially or wholly consumed, or would at any rate deteriorate under continued exposure to the intense heat, while the carbonisation of the remaining wood was being completed. Hence, woods of very different densities, as well as pieces of very different thicknesses, should never be mixed together. There is also another objection to carbonising woods of different densities together. The quality and, consequently, also the use to which the charcoal is put, depends to a great extent on the density of the wood; so that the different qualities of charcoal should be kept apart from the beginning, as it would be impossible to separate them afterwards. Very thick pieces must, in any case, be split up in order to hasten the carbonisation, and the thicker billets may also be split up so that they may be carbonised with thinner ones. The pieces to be carbonised should be dressed straight, in order that they may pack close together. Unsound wood should never be used, as it will yield no charcoal. Lastly, if the wood is

to be carbonised in retorts or close furnaces, it should be as dry as possible in order to economise both fuel and time ; and if it is to be carbonised by any other method, which requires the admission of a certain considerable quantity of air to produce the necessary temperature, it should be just dry enough to develop that temperature without burning too rapidly and being consumed to no purpose. In the latter case, the quantity of moisture allowable will be in direct proportion to the dryness and high temperature of the air, the defective nature of the covering over the kiln, and exposure to winds.

#### SECTION I.—CARBONISATION IN RETORTS AND CLOSE OVENS.

In every method of carbonization in retorts or close ovens the double object is sought of obtaining the charcoal and of securing the products of distillation, thus allowing no portion of the wood to go to waste.

A convenient and general form of oven used in England consists of a cast-iron cylinder laid horizontally in masonry with a fireplace below. The wood is put in at one end, which is then closed with a well-fitting iron door that is carefully luted to render it completely gas-tight. For the first two or three hours the fire is kept low to dry the charge of wood. It is then driven hard until carbonization is complete ; but if the operation is conducted too quickly, the yield of charcoal may be reduced by as much as 30 to 45 per cent. A charge of 100 stacked cubic feet of wood requires 12 to 13 hours to give the best results. During carbonization the following process takes place. First, the free moisture of the wood is driven off ; then, as the temperature is raised and decomposition of the wood occurs, acetic acid and water are given off, followed by tar and volatile oils, and lastly by uncondensable gases, *viz.*, carbon monoxide and dioxide, and marsh and olefiant gases. The products of distillation escape through a pipe at the other end, whence they pass into the condenser. The condenser pipe gets rapidly clogged with tarry matters ; it must therefore be composed of short straight lengths that may be speedily cleaned out. At the exit end of the condenser pipe there are two outlets, through the lower one of which pass out the condensed products, consisting of water, pyroligneous acid, ammonia, tar, naphtha, and various oils and resinous matter ; through the upper the uncondensable gases above mentioned, which, instead of being allowed to pass off into the atmosphere and taint it, are conducted into the fireplace to feed the fire. In order to utilise to its fullest extent the heat of the

fire, the products of combustion, with the heated air, are made to circulate in an enclosed space, between the oven and the floor of a drying room above, before passing up the shaft of the chimney. In this drying room is stacked the wood to be carbonized afterwards. Any number of ovens may be set up side by side in the same building. The condensed products of the distillation are delivered into a tank, where the tar settles down to the bottom and is drawn off, while the supernatant liquid, after the lighter tarry and carbonaceous matters which rise to the top have been skimmed off, is pumped up into a reservoir containing a solution of lime or soda to form the acetates, from which the pure acetic acid of commerce may then, if required, be distilled after admixture with sulphuric or hydrochloric acid. When the run of liquid from the condenser ceases and the exit pipe from the cylinder becomes cool, it is known that the distillation, in other words, the carbonization, is complete. The fires are allowed to die down, the door is opened, and the charcoal raked out into a deep iron waggon with a close iron cover, which is luted down with clay to prevent the charcoal from taking fire in contact with air.

In some other works in England, instead of the cast-iron cylinders, they use more or less square ovens, into which the charge is introduced in sheet-iron waggons. The waggons are filled up to about 18 inches above the sides; with the progress of carbonization the contents ultimately subside below the sides. In this method the charcoal is at once withdrawn in the waggons and thus runs no risk of breaking.

The disadvantages of the cast-iron cylinders are a liability to crack, and a larger consumption of fuel owing to the thickness of the plate. On the other hand, the wrought-iron ovens are apt to leak at the joints and doors, to warp with the heat, and to be more quickly corroded by the acid products of the distillation. The yield of charcoal in both kinds of apparatus slightly exceeds 25 per cent. of the weight of well-seasoned wood; but this of course leaves out of account the fuel consumed below the cylinder to effect carbonization.

A form of apparatus much used in France consists of a cylindrical cast-iron retort, which, after being charged and closed, is hoisted into a close-fitting brick furnace or jacket with a fire-place at the bottom. A strong air-tight cover is put over the furnace. As soon as the distillation is finished, the retort is hauled out and a fresh one put in. In another very convenient form of apparatus, M. Kestner's pattern, the retort is fixed and built round with masonry. Both patterns are very simple and less costly than the

two English forms described above, but their object is principally to obtain a good yield of pyroligneous acid.

Apparatus have also been invented for distilling sawdust. Owing to its finely divided state, sawdust cannot be distilled in the ordinary retorts, as it forms a dead mass and becomes carbonised only superficially. For this reason, the sawdust is fed into the retorts very gradually, and is constantly moved on, on an endless iron band, until it finally leaves the retort at the other end in a fully carbonised condition. The charcoal is comparatively useless, but it may be made up into patent fuel.

Very successful carbonization may be effected in ovens built entirely of brick masonry and ending in a narrow chimney. Such ovens may be made large enough to take up to 6,000 cubic feet of wood. The wood is carefully packed inside, several vertical flues, filled loosely with the smaller pieces, being formed, in order to secure a free through-draught and to distribute it uniformly. Just enough air is admitted through the sole of the furnace to carbonize the wood. The products of distillation pass out into convenient receptacles through openings at the sole of the furnace. The carbonization is complete when the smoke issuing from the chimney turns from black to a bluish white.

The great disadvantage attaching to all fixed works is that the wood to be carbonized has to be carried to them, often at prohibitive expense. Hence their general inapplicability, except when the products of distillation obtained serve to cover the increased expenditure.

To overcome this drawback various portable apparatus have been devised, two of which are described below. One of these, designed with the double purpose of effecting carbonization and securing the products of distillation, is M. Moreau's patent. It consists of a cast-iron furnace, having the shape of an octagonal prism and capable of containing about 400 stacked cubic feet of wood (roughly about 120 maunds). Tubes fixed at the top carry off the products of distillation, while ingeniously designed self-acting valves at the bottom allow of the wood inside being lighted, as well as regulate the entry of air to keep up the combustion, the valves completely closing of themselves when this becomes too active. The whole apparatus can be quickly taken to pieces, and transported and set up again with ease. The carbonization is completed in 30 hours, and the yield, by weight, of charcoal is said to reach 23 to 24 per cent.

Another apparatus, the invention of M. Dromart, consists of a beehive-shaped oven, capable of containing about 800 stacked cubic



feet, and composed of plates of sheet-iron which fit closely together at the edges and are supported on a strong circular iron frame. This oven, open at the bottom, is placed over a fire-place built up with brick or clay and provided with numerous holes through which the heat from below can enter it. Some of these holes are covered over with a sheet-iron plate to moderate the heat. The oven terminates in a chimney that can be closed or opened at pleasure. The wood is stacked within the oven through a side-door. When lurid vapours begin to issue from the chimney, an event that is not long in occurring, the carbonisation is complete. All that has then to be done is to close the chimney, put out the fire under the oven, and allow this latter to cool down. The apparatus is extremely portable, and the fire-place may be built up anywhere without skilled labour.

As contrivances merely for the manufacture of charcoal, neither of these two last-described or other similar apparatus are likely to come into general use, as they can never supersede the inexpensive wholesale methods of carbonization in ordinary kilns, which can, besides, take in pieces of any size without requiring them to be split up small. Those permitting of the utilization of the products of distillation must, however, at no distant date, enjoy a certain extended application in India in meeting the large demand that is sure to arise for acetic acid, wood spirits, ether, creosote, tar, &c.

## SECTION II.—CARBONIZATION IN ORDINARY KILNS.

In every system of carbonization in ordinary kilns, the covering over the wood is a rough one (generally of leaves and earth), the wood in the kilns has to keep up its own combustion, and the emplacement of the kiln is not in any way built up.

There are numerous forms of such kilns, but only four of them, which are simple to build and manage, and are thoroughly practical and in very general use, will be described. They are (1) the paraboloidal over-ground kiln, (2) the paraboloidal pit-kiln, (3) the hill kiln, and (4) the prismatic kiln.

### ARTICLE 1.—THE PARABOLOIDAL OVER-GROUND KILN.

The shape of the kiln, when it is ready to be fired, is very nearly a paraboloid of revolution, the formula for the contents of which figure is  $\pi r^2 \times \frac{h}{2}$ , or, expressed in terms of the circumference,  $C$  (which basal dimension alone can be measured),  $\frac{C^2 h}{8\pi} = \frac{C^2 h}{25 \cdot 12}$ . As the kiln is generally more acute than a paraboloid and has

straighter sides, it is usual to diminish the contents given by the formula by 4—6 per cent.

### 1.—*Size of the kiln.*

The larger the kiln is, the less will be the relative quantity of covering material used, the more limited the space occupied, the fewer the men required, and the smaller the proportion of wood consumed in producing the heat necessary for carbonizing the remainder, and hence the lower will be the cost of carbonization. On the other hand, the larger kiln requires greater skill both to build up and to manage during the burning, and produces a harder charcoal. The largest kiln of the kind made in India seldom contains more than 1,500 stacked cubic feet of wood. A very convenient size for persons possessing little skill is one containing about 600 cubic feet.

### 2.—*Emplacement of the kiln.*

The site selected should be sheltered, even, and level, and it should be close to abundant water and to the wood to be carbonized. If the quantity of wood is large, there ought to be room enough for several kilns, as the same party of burners can just as easily manage several kilns as a single one. The nature of the soil is also of considerable importance. A soil that is too free and porous would allow too strong an upward draught of air to pass through it into the burning wood above, while a too stiff soil would, on the contrary, cause the kiln to burn too slowly. A loamy sand is the best, as, besides possessing average stiffness, it absorbs at once the condensed vapours given off by the wood, which in a stiff soil would clog the surface and interfere with the carbonization. It is absolutely necessary that the soil of the entire site should be uniform, otherwise the kiln would burn more rapidly at some points than at others, the result being unequal subsidence and consequent extensive and frequent breakages, and hence unequal carbonization and unprofitable waste of wood.

If a new site is used, it must be very carefully prepared. Such preparation will consist in (1) clearing away all vegetation by the roots; (2) removing all stones, for carbonization will be unnecessarily slow over boulders and injuriously quick over smaller elements; (3) raising the site about 8 to 12 inches in the middle and sloping it down outwards in every direction, so as to allow the liquid products of the kiln, which cannot be absorbed into the soil, to run out

freely. The soil should then be allowed to settle for two or three months until it becomes close enough. If it is damp, it should, just before it is used, be warmed up and dried by burning over it a thick layer of dry twigs and leaves.

An old site is preferable to one that is perfectly new; in the former the soil has already undergone the necessary preliminary preparation, and it is a matter of experience that in a fresh-made site the yield of charcoal is from 10 to 17, and sometimes even 25 per cent. smaller. But of course a site on which a kiln has just been burnt cannot be used again until the moisture that it has absorbed from the kiln has completely dried up.

Even before using an old site, the surface must be carefully re-dressed and the numerous pieces of charcoal, left in it from the previous burning, broken up small and mixed up intimately with the soil.

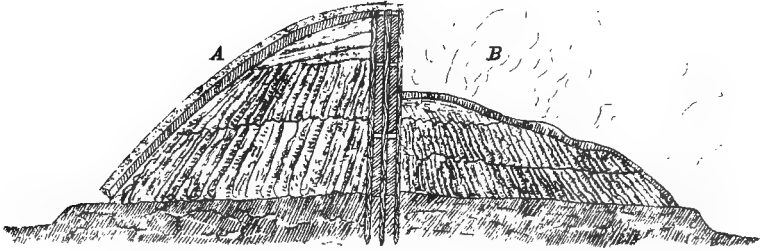
### 3.—*Building up of the kiln.*

In building up a kiln, the pieces of wood may (*a*) be all laid horizontally, or (*b*) horizontally only in the topmost tier with the rest set up more or less vertically. In the first case the system of piling up the wood is the same as that followed in constructing the paraboloidal pit-kiln, in the Article on which it will be found described. For this reason, and also because a kiln so formed is much more difficult to build and is more liable to unequal subsidence and breakages (these drawbacks increasing with its size), nothing further will be said regarding them in this Article.

First of all, the chimney or flue through which the kiln is fired has to be formed. For this purpose three straight upright posts, of the same height as the future kiln, should be firmly fixed in the centre of the site, about a foot apart from each other, and bound round with wattling or strands of twisted grass. As the kiln rises, readily ignitable chips of wood or half-burnt fragments obtained from a previous burning are loosely thrown into the flue until it is nearly full. According as the wood in the chimney is to be fired from above or from below, the largest fragments are placed at the bottom and the smallest and most combustible at the top, and *vice versâ*. In either contingency, if the soil is damp, a small board must be placed over the ground under the chips, to prevent the fire from being smothered by the steam rising up from the ground.

The next step is to pile up the wood to be carbonized. To ensure a circular section to the kiln, the base should be accurately pegged out. The wood is arranged in three or more tiers, according to the

size of the kiln. *Fig. 66 A* shows the disposition of the wood in  
**Fig. 66.**



*Paraboloidal over-ground kiln with upright stacking.*  
*A.—Before firing. B.—Carbonization complete.*

a kiln composed of three tiers. The upright pieces should rest on their thick end, so that they may incline more and more towards the chimney the further away they are set up from it; there is no other way of giving to the sides of the kiln the slope necessary for their stability, which slope should nowhere exceed  $65^{\circ}$ . It is evident that all the upright pieces in the lower tiers should be of equal length in one and the same tier. Those in the topmost tier, being laid horizontally, must, on the other hand, be necessarily of different lengths to admit of being closely packed together and to enable the apex of the kiln to be properly rounded off. It is not necessary that the whole of a tier should be completed before the next one is begun; indeed, it is always more convenient to commence building up this latter when the other has been about half completed. In the topmost tier, as in all the rest, the laying of the pieces should progress from the chimney outwards, and great care must be taken to secure an even paraboloidal outline without placing any piece on the outside in such a way that it must fall off when the kiln begins to subside with the progress of the carbonization. The packing should everywhere be as close as possible, for the volume of every piece must diminish considerably as it becomes carbonized, thus causing all originally empty spaces to grow larger and thereby diminishing the stability of the kiln. As a further precaution, the numerous intervals that must remain even after the most careful packing should be filled up tight with thin pieces and chips, preferably of completely dry or, better still, if at hand, of half-carbonized wood.

If the kiln is to be fired from below, a narrow passage, extending as far as the chimney, should be left open along the ground,

whereby the combustible material at the bottom of the chimney may be reached when the kiln is ready to be lighted. The passage is easily made by laying a straight pole on the ground and arranging the billets on each side of it in the way that a house is built up with cards, the pole being finally withdrawn.

The wood placed immediately against the chimney should consist of thin split pieces, dry enough to take fire readily. The best material to use, if obtainable, is the half-charred wood from a previously-burnt kiln. The packing near the chimney should be specially close, all interstices being filled up with chips and shavings.

As split wood takes fire most readily on the split side, such wood should be placed with this side facing the chimney or downwards, as the case may be. This position of the pieces also helps the wood to be packed with greater ease and closer together.

The thickest pieces should be placed where the heat will be strongest and steadiest, that is to say, about midway between the chimney and the periphery.

#### 4.—*Covering the kiln.*

In order to prevent the unchecked entry of air amongst the wood and to regulate the indraught during the carbonization, the covering put over the kiln should be such that, while it is easy to put on and take off or increase and diminish in thickness at any point, it should subside evenly as the kiln subsides, without falling away or opening out in rents and fissures. Experience has shown that it should always consist of two parts, (1) an inner layer composed of moss, sods of turf, green weeds, leafy twigs or green grass, and (2) an outer one of wet-earth plastered or thrown over the first.

The inner covering must obviously be formed with some green, yielding fibrous material that does not take fire too easily and is at the same time able to hold together, however much the kiln may subside. Moss and close turf are the best for the purpose, and grass the worst. When grass is used, it ought to be short, soft, and fine. Whatever the material is, it should be the same throughout, otherwise the covering will both lie and subside unevenly.

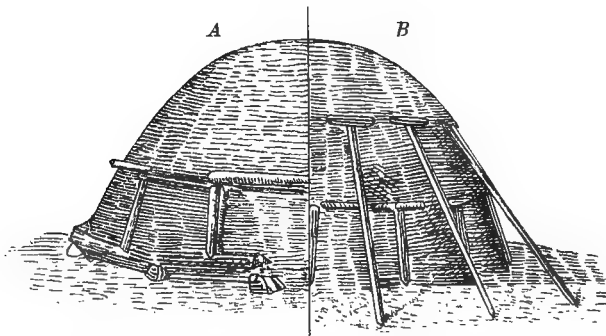
For the outer covering we require a soft earth which will not form a too stiff and impermeable mass when moistened, will not harden and become full of cracks with the great internal heat of the kiln, and will not conduct heat too rapidly, but which will at the same time not lie so loosely as to fall away too easily and not be so porous as to be too freely permeable to air. Hence the best natural

material is loam containing a large proportion of vegetable remains, and the best material of all is the earth obtained from an old kiln with its large admixture of ashes and fine cinders.

The first covering should be laid on beginning from the top, so that every portion of it may be supported and prevented from slipping downwards by the overlapping portion immediately below. It should be thick enough to prevent the earth of the outer covering from falling through amongst the wood and thus retarding and even preventing carbonization. In order to obtain a good indraught of air while the kiln is taking fire, the covering should not at first be put on too thick near the ground, and may even be left open at a few points there, such openings being stopped only when the carbonization is in full progress. Similarly, the vent of the chimney should also be left open until then.

The earth for the second covering should be freed of stones and other large fragments, which would destroy its even texture and let in unequal draughts of air. All clods should be broken up fine and the whole mass of material thoroughly well worked up until it is of uniform texture throughout. For the top of the kiln and those portions which have a gentle slope, the earth need only be moistened just sufficiently to keep the particles together, and then it is best thrown on with a shovel, so that it may get evenly distributed and ultimately rest safely at the proper angle of repose. For the steep portions, especially when grass is used inside, the earth should be made into a sort of thick mud and plastered over the grass. To prevent the earth from slipping off the steeper portions, it has to be propped up, especially near the ground. Two simple and effective modes of propping are shown in *Fig. 67*.

Fig. 67.



*Mode of propping up covering of kiln. Different styles shown at A and B.*

5.—*Firing of the kiln.*

If the kiln is to be fired from below, a torch is formed at the end of a long pole with grass and some highly inflammable chips of wood. The lighted torch is inserted into the open passage left along the ground and pushed home against the bottom of the chimney, the pole being at once withdrawn. The draught along the ground and up the chimney carries the fire into the latter, from which then as centre it is able to spread outwards amongst the wood to be carbonized. The chips and other small fragments of wood placed in the chimney are quickly consumed; as they subside, fresh pieces must hence be gradually stoked in from the top. Ultimately, when the fire has become established and has begun to spread outside the chimney, this latter is filled up tight to the top with short billets of wood. If this last operation is not properly done, the chimney will soon become empty and cause the wood from the sides to fall in, thus leading to unequal subsidence and to the breaking up of the kiln. After the chimney is full, and even earlier if the wood is very dry or a strong wind is blowing, the tunnel along the ground is filled up with short straight billets well packed together. When the combustion inside the kiln is in full progress, the covering is completed over the open extremities of the chimney and tunnel. It requires some experience and judgment to close these openings at the proper time.

If the firing is to take place from above, a dishful of live coal is dropped into the chimney and the fire worked into the chips below with a thin bar of iron or even a green sapling. The fire is stoked from time to time with small pieces of dry wood, and, finally, when the wood in the chimney is in full combustion and the fire has reached the bottom, the chimney is filled up and closed in the same manner as in the method of firing from below, already described.

Firing from below is always troublesome, and the necessity of leaving a passage open along the ground breaks up the regularity of the stacking and renders the kiln liable to excessive subsidence on one side during the process of carbonization. To compensate for these drawbacks, it is more certain in its results, as unless the chimney is properly constructed and the fire skilfully stoked, fire lighted from above may fail to reach the bottom of the chimney, thereby rendering the carbonization of the lowest tier of wood a difficult matter, or at any rate entailing the overburning of the wood in the upper tiers after it has already become carbonized.

*6.—The process of carbonization.*

Whether the kiln is lit from below or from above, the whole of the wood in the chimney must be on fire before the burning is allowed to extend into the wood beyond.

Assuming that the wood in the chimney is fully ablaze first, the fire spreads thence outwards in the form of an inverted cone with an ever-widening base, until the whole of the kiln is on fire. This mode of progression of the fire is explained by the principle of the parallelogram of forces. The heated air and other gases tend to rise vertically, while lateral contact of the wood to be carbonized creates a tendency for the fire to extend horizontally. The resultant of these two tendencies is at first an oblique line not far removed from the vertical, and since the height to which the fire can extend is limited, and the temperature inside the kiln is constantly rising, the horizontal spread of the fire becomes more and more conspicuous until the whole of the wood at the bottom is carbonized. Thus the carbonization proceeds progressively from the top downwards.

During the process of carbonization large quantities of various gases are given off. The whole of these gases being unable to leave the kiln, what remains behind condenses inside and trickles down through the lower tiers of wood to the ground, where it is absorbed or from which it flows away through the foot of the kiln.

While any piece of wood is being carbonized, first of all steam, the characteristic colour of which is a bluish-grey, issues forth. This is followed by russet-coloured vapours, which would, if condensed, yield pyroligneous acid, tar, wood-spirit, &c. When the carbonization is complete, if the burning is still continued, a clear blue flame proceeds from the carbonized wood, proving that only charcoal is left and is being burnt away.

Some of the gases given out by the carbonizing wood form explosive mixtures with the oxygen of the air; if they are not given a free vent, explosions will take place inside the kiln, disarranging the wood and causing the covering to burst.

*7.—Conduct of the carbonizing operations.*

If the formation and expansion of the fire-cone took place uniformly in every direction, all that would be required would be to keep the covering sufficiently pervious to air along the edge of the expanding cone (that is to say, at the level at which carbonization was going on) and to maintain it air-tight elsewhere, especially



over those portions of the kiln where carbonization was completed. Hence, the first thing that would be done after closing the flue of the chimney would be to pierce small vent holes, 1 to 2 inches in diameter and about 2 feet apart, all round the kiln a foot or so below the apex. The object of these holes, which could be easily made with a bamboo or sapling pointed with iron, would be to admit the necessary amount of air for carbonizing the wood at the top of the kiln and allow the vapours and other gases of distillation to pass out freely. When the carbonization at this level was complete, which fact would be recognized by the pale blue colour and transparency of the smoke, the holes would be closed and a new line of them opened 1 to 2 feet lower down. In this way the charcoal-burner would gradually effect the carbonization of the entire kiln, the natural spread of the fire-cone being aided and regulated by means of the holes. He would then cover up the kiln as thickly as possible in order to stop all combustion, and in a few days the kiln would have cooled down enough for the covering to be taken off and the charcoal removed.

Under actual conditions such extreme uniformity is unattainable, owing to several causes of irregularity, the principal of which are the following :—

- (i). Inevitable defects in the packing of the wood, in consequence of which unequal draughts are produced, leading to more rapid carbonization and, therefore, more sinking at some points than at others.
- (ii). Differences in the amount of moisture contained in different pieces of wood.
- (iii). Difference of density, even when only a single species is used.
- (iv). Movements of the atmosphere, from which the kiln can never be effectually screened.
- (v). Unequal nature of the site.
- (vi). Unavoidable errors of judgment, to which the most skillful are liable.

To overcome these various causes of irregularity requires no little skill and experience and unremitting care and watchfulness on the part of the charcoal-burner. To gain his end he must have recourse to one or more of the four following measures, which constitute the whole of his duties at the present stage of his work :—

I.—ERECTOR OF A SCREEN ON THE WINDWARD SIDE OF THE KILN.—The cheapest form of screen is one of thatch supported against upright posts firmly fixed in the ground. But the first precaution

to take, which may save the necessity of a screen, is to select a sheltered site with a close fringe of trees standing to windward.

II.—INCREASING THE DRAUGHT.—Whenever unequal subsidence takes place, there is proof positive that in the higher portions carbonization has been going on more slowly than elsewhere. If the sinking at the lower points is not too rapid, then it is evident that the burning in the higher portions requires to be accelerated, in other words, that more air must be admitted inside them. This is done by making new vent-holes there or enlarging existing ones. The size of the holes and the intervals between them will depend on the degree of acceleration required. The new holes made need not be all at one and the same level.

Sometimes, it may happen that the rate of carbonization is everywhere too slow. The remedy for this is to make a line of vent-holes all round the kiln immediately below the level at which carbonization is actually going on. The object of these vent holes is not only to increase the inflow of atmospheric oxygen, but also to give free exit to the vapours given out during carbonization, the rapidity of which is impeded by them. The size of the holes and the intervals between them will depend on the amount of moisture in the wood and the slowness or rapidity with which the particular wood burns. If a screen has not been erected or the wind is constantly changing, no holes should be made on the windward side, and as the wind shifts about, some of the holes must be closed and new ones opened or enlarged. Every hole must be closed as soon as a clear blue flame or bluish transparent vapours issue forth.

The vent-holes are thus made to fulfil the double object (i) of securing equal combustion on every side, and (ii) of conducting the carbonization with the requisite speed. The necessity of vent-holes increases with the size of the kiln, and, under favourable circumstances, a small kiln situated in a sheltered spot may hardly require any at all.

III.—DIMINISHING THE DRAUGHT.—This is the opposite of the preceding operation; and consists in increasing the thickness of the outer covering wherever the kiln, by sinking too rapidly, affords a certain indication of over-rapid combustion. Over-rapid combustion can be detected even before sinking actually takes place: at such points an excessive quantity of dense smoke issues continuously.

As the carbonization progresses from the top downwards, the outer covering over the portions, where the process has just been completed, should be strengthened until no more smoke finds its way through it; and wherever, from any portion that has been

already carbonized, smoke is seen to come out, additional earth should be thrown on until it ceases.

The intense heat of the kiln bakes the moist covering of earth into a hard brick-like mass in which numerous cracks open out. It is impossible to close such cracks, and the only way to render the covering effective again is to quickly pull off the loose pieces of baked earth and replace them with fresh material. Some of the pieces may even be broken up fine on the kiln with a mallet. Not unfrequently it is impossible to stop smoke without moistening the outer covering; but the necessity for such action occurs only towards the end of the entire carbonization, when there is not sufficient humidity left inside to keep the covering moist with the vapours given out.

IV.—FILLING UP HOLLOWs.—However carefully the wood is packed or the regulation of the draught attended to, it is impossible to entirely prevent the formation of hollows owing to the wood at certain points burning so fast as to become partially or wholly consumed. If such hollows are not at once filled up, the further settling of the wood will cause the kiln to fall in at those points. Hollow places may be detected by beating the sides of the kiln with a club; where there is a hollow, the cover will yield or even fall in, or return the tell-tale sound.

To fill up a hollow the covering over it should be quickly torn open with a hoe and short billets of wood thrust in one after another as tight as possible, the covering being restored without delay. In doing this work the utmost dispatch should be used, and hence a quantity of filling and covering material, sufficient for all contingencies, should always be kept ready at hand. When the covering is cut open, a good deal of flame will issue through the opening.

GENERAL.—In order to do the needful at the right moment, the kiln should be constantly watched and tended by a number of men sufficient for all contingencies. For a single kiln containing up to 800 maunds of wood, or even for two kilns of that size, two men will suffice. During daylight the watching of the kiln and conduction of the burning offers no special difficulties; but during the darkness of the night accidents are especially to be feared, particularly if high winds blow. On this account, every evening, before nightfall, all hollows should be examined and filled up and all weak places thoroughly overhauled and strengthened. If the night is expected to be stormy, additional covering should be put on everywhere, and only just enough vent holes left open to prevent the fire from going out. Lastly, at short intervals all through the night, the kiln should be carefully examined on every side. Bun-

dles of dry grass should be kept handy, in order to get up plenty of light in case of accidents.

When, with the gradual downward progress of the carbonization, clear blue flames issue from the base of the kiln, the work is complete and the fire must be caused to die out without delay. This is done by shovelling on fresh earth and moistening the covering until smoke ceases to come out. A little superficial smoking, due to the conversion of the moisture in the covering into steam, must not be mistaken for real smoke. It is especially along the base of the kiln that draughts are likely to continue to enter, and it is here that the covering should receive extra strengthening.

#### 8.—*Opening of the kiln.*

Even after the fire has gone out, the temperature inside the kiln will still be high enough to cause the charcoal to light up again, if air were admitted. On this account the kiln must be allowed to cool down sufficiently before it is opened. If we waited until the contents were cool enough to be comfortably handled, a week or even a whole fortnight might elapse. In practice, therefore, the work of taking out the charcoal may be commenced, according to the size of the kiln and the skill of the burners, from 1 to 3 days after the carbonization has been completed.

To prevent the charcoal from burning it should be taken out only at night, when the air is cool and damp and burning pieces can be at once detected by their glow and put out. The simplest plan to follow is to cut open a section of the kiln on one side, pull down quickly as much charcoal as possible, and cover up the kiln without delay. When so much charcoal has been picked out, another section adjoining the first should be pulled down, and so on until a complete circuit of the kiln has been made. If the remaining charcoal is also cool enough, a second and even more such tours of the kiln may be made. A small kiln may be emptied out in a single night; but usually the work requires at least two nights, as the charcoal in the centre is always hot enough to take fire readily, and covering it up for another night brings about the necessary reduction of temperature. The emptying of a large kiln may take several successive nights.

As the charcoal is picked out, it should be spread out on the ground, otherwise a single piece taking fire would set the whole heap burning. When spread out thus, individual pieces becoming aglow are detected at once and put out with a few drops of water.

The Indian charcoal-burner is often accustomed to empty out even a large kiln in a single operation, and to prevent all risk of fire, he deluges the hot charcoal with water. Nothing could be more reprehensible, as the moistened charcoal not only breaks up into innumerable small fragments, but also loses quality.

As soon as the charcoal is cool enough to be handled, it should be sorted and at once put away under shelter, for charcoal absorbs moisture greedily and becomes depreciated thereby. If there is a demand for it, the very small charcoal that is mixed up with the dust of the kiln should be sifted out, constituting then the lowest class of charcoal.

However skilfully the carbonization has been conducted, a very appreciable portion of the wood will always be found incompletely charred. Such pieces, as already recommended before, should be utilised in new kilns as filling material for the chimney and hollows and for placing next to the chimney. But if they are very numerous, it will be found convenient to complete their carbonization separately in a kiln made up entirely of such stuff; mixed up with fresh wood in any other manner than that indicated above, they would be reduced to ashes by the time the latter was carbonized.

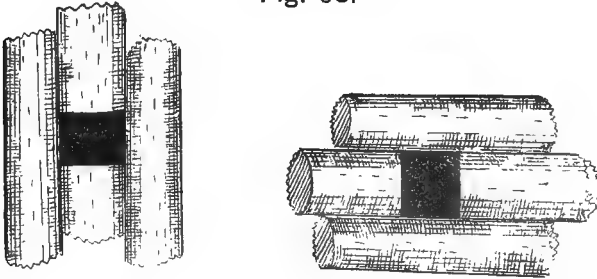
#### ARTICLE 2.—THE PARABOLOIDAL PIT-KILN.

In this system, a circular pit from 1 to 2 feet deep is dug, with a level bottom and sides sloping enough not to fall in. The bottom of the pit is first strewn over with a layer, from 4 to 6 inches thick, of dry leaves and twigs, and then the kiln is built up. The object of this foundation of loose and highly combustible material is (i) to preserve the wood to be carbonized from direct contact with the soil, which, besides that it may itself be originally moist, must, during the process of the carbonization, become sodden with the liquid products of distillation, and (ii) to ensure the fire extending amongst the wood at the bottom of the kiln. The pieces of wood to be carbonized are laid horizontally—some radially, others tangentially. Hence, to pack close, they must be of all sizes. Before beginning a new layer, all empty spaces in the one just completed should be filled up with small pieces, preferably of dry wood. It is superfluous to add that every layer should be arranged as horizontally as possible.

The manner of forming the flue requires to be described. The billets forming its sides in alternate layers of the wood are arrang-

ed respectively as represented in *A* and *B* of *Fig. 68*. As the

*Fig. 68.*



*Mode of constructing flue of horizontally-laid paraboloidal kilns.*

horizontal position of the pieces precludes any tendency for them to fall in, no posts are necessary to support the sides ; but to help to form the flue straight and vertical, a straight billet may be held upright in it until the kiln has been built up.

The firing can of course take place only from the top, in the manner described on page 186. The management of the covering is, however, at first different. Since there is absolutely no danger of over-rapid combustion within the pit, the sides at the ground-level should be kept open for some time to allow the fire to spread freely downwards, and, in order to prevent the wood at the top from burning too fast in the meanwhile, no vent-holes should be pierced there. It is only when the wood within the pit is in full combustion that the covering near the ground should be completed, but even then it should be lighter there than elsewhere, and a vent or two may have to be left on a level with the ground up to the very end of the carbonization. Some charcoal-burners, in order to introduce a draught into the pit, excavate a narrow oblique shaft in the sides of the pit at the two extremities of a diameter and opening into the bottom of the pit. Needless to say that the shafts are not closed at all until carbonization is complete.

By stacking horizontally we secure the very signal advantage of being able to utilise pieces of all lengths and thicknesses, thus saving the very heavy cost, imposed by the vertical method, of cutting up all the pieces to one length and of splitting them to more or less the same thickness, and also being able to build up a kiln with the produce of the few nearest trees. It is mainly on this account that the Indian charcoal-burner always lays his wood horizontally, and will have nothing to say to vertical stacking, even when the circumstances of the case render that method preferable.

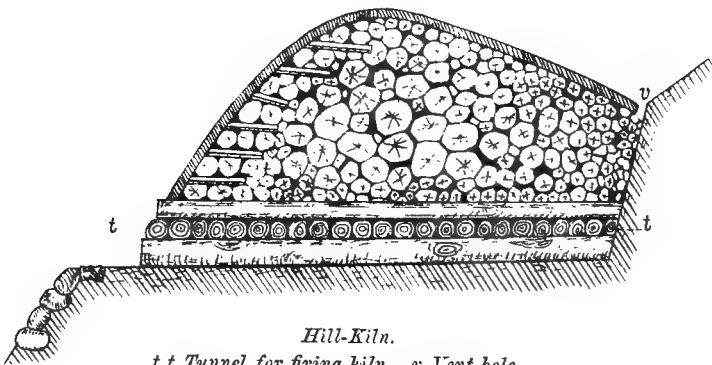
On the other hand, the packing in horizontal laying is extremely irregular and requires infinite pains to do well, and also consumes much time. It is for this reason that the overground form, the burning in which is so much easier to conduct, is so often given up for the rather primitive pit-form here described, in which loose and careless packing has not the same serious consequences. Although no exact figures are available, there are sufficient data to prove that the yield in pit-kiln burning is very much less than in overground burning, the outturn of charcoal seldom exceeding 15 per cent. of the wood used. It is, however, well adapted for charcoal manufacture on a small scale when skilful burners are not obtainable. The local name in the Dehra Dún for the pit-kiln is *bhadi ka bhatta*, literally, the carpenter's kiln.

#### ARTICLE 3.—THE HILL-KILN.

On hillsides the construction of any of the kilns hitherto described is out of the question; a level site of even quality could be obtained there only at prohibitive expense, and the draught from the four sides can never be made equal, being always greatest from the side of the valley and almost totally wanting on the side of the hill. Hence the necessity of constructing a special kind of kiln.

The terrace on which the kiln is to be built should be made to slope slightly outwards. The outer portion of the terrace, being necessarily made-ground and open towards the valley, is pretty freely penetrable to air. To neutralise this inequality, which is still further exaggerated by the absence of any draught from the side of the hill, the largest and hardest and greenest pieces should be packed at the valley end of the kiln, which should also be built up highest. Moreover, the kiln should, for obvious reasons, be made to lean up against the hill, and to this end the side of the hill should not be cut vertical but sloping at an angle of about  $30^{\circ}$  (see Fig. 69).

Fig. 69.



Hill-Kiln.

*t t* Tunnel for firing kiln. *v* Vent-hole.

To secure a through draught, a tunnel (*tt*) is left along the whole length of the kiln, and it is by this tunnel, which is afterwards filled with small combustible wood, that the kiln is fired. At *v* the covering is omitted, in order to draw the fire inwards and upwards. The fore end of the tunnel is left more or less open for several hours after combustion has begun. On its being closed, several holes are made both in the outer face and sides of the kiln and also one on each side of the vent-hole *v*, which itself is kept open until carbonization is nearly complete.

The outer face and sides of the kiln are often rather steep, and the covering of earth must then be kept in place with the aid of struts, as explained in *Fig. 67* above.

In a report written by Mr. Heinig in 1880, whilst he was at the Forest School, he says that he found it an advantage to form a vertical chimney rising up from the inner extremity of the tunnel, and to fire the kiln through this chimney as well as through the tunnel. The chimney, no doubt, renders the firing very much easier, but its absolute utility has still to be proved by a larger number of experiments than he was able to try. The best way to secure the carbonization of the wood near the hill is to make the height of the kiln diminish towards the hill and to keep the vent-holes open on the top along the edge of the cutting.

With skilful burning, the yield in this style of kiln should hardly, if at all, fall short of that obtainable from any other kind of kiln.

#### ARTICLE 4.—THE PRISMATIC KILN.

The shape of the prismatic kiln resembles to a certain extent an ellipsoidal dome springing up from a rectangular base. If *l* and *b* be respectively the length and breadth of its base, and *h* its dimension where the height is greatest, then the stacked contents will be approximately  $= \frac{1}{4} l b h$ .

Such kilns are most conveniently built up with straight long pieces, of more or less the same thickness, running through the entire length of the kiln; but the prismatic shape is very frequently adopted even in the absence of such pieces, because it is on the whole easier to form and requires the wood to be much less cut up than the paraboloidal form, although it is, on the other hand, more liable to breakages from irregular settling and more difficult to cover properly. There is no chimney, but a tunnel is left along the ground running through the entire length of the kiln and filled with combustible material, which is fired at both ends. In India prismatic kilns are usually made much larger than paraboloidal ones. The outturn of charcoal does not differ materially from that



obtained from the latter class of kilns when these are built up with horizontally-laid wood.

### SECTION III.—CARBONIZATION IN OPEN PITS.

The pit is from 3 to 5 feet deep and 5 feet and upwards in diameter, the sides being made sufficiently sloping to support themselves. First of all, it is filled up with dry twigs and branchlets, which are fired and allowed to burn down freely. When the burning has progressed so far that the wood inside is all aglow and has ceased to give out any smoke, the first instalment of the wood to be carbonized is thrown in. This wood is allowed to burn on until, in its turn, it no longer emits any smoke, when a second instalment is thrown in. This process is repeated until the pit is full of glowing coal. The entire glowing mass is then covered up with a layer of moist earth, thick enough to exclude air. After two or three days the pit will be sufficiently cool to be opened and the charcoal taken out.

This is an extremely wasteful way of making charcoal, but as it requires no skill at all and next to no supervision, it may be adopted where there is plenty of waste wood that has no other use and the demand for charcoal is relatively small.

### SECTION IV.—YIELD OF CHARCOAL.

The yield will depend on various circumstances, the principal of which are—

1. *The nature of the wood used.*—Dry wood yields more charcoal than moist wood; resinous and oily woods more than other kinds (since both the resin and the oil contribute a large proportion of the heat necessary for the carbonization); and soft woods more than hard woods (since the volatile products of distillation are more easily expelled from the looser tissues of the latter). Branch-wood, as it contains more reserve materials and less ligneous matter, yields less charcoal than the wood of the stem.

2. *The nature of the site.*—On a site that is uniform throughout and is well-sheltered, and is also one that has been frequently used before, so that its peculiarities are thoroughly known, the yield will obviously be largest.

3. *The state of the weather.*—Still weather is much more favourable than windy weather, especially if the wind constantly shifts or blows in gusts. Very dry weather is just as unfavourable as steady rainy weather. In dry weather the covering breaks

open very frequently and requires to be constantly moistened ; on the other hand, in rainy weather the covering remains so moist that the steam and other vapours, which form in the interior, do not find sufficient vent, and carbonization is consequently retarded, and, if the rain is heavy enough, the covering may be washed away. When carbonization in wet weather cannot be avoided, a thatch roof should be put over the kiln.

4. *Proper control of the carbonization.*—The yield is largest when the progress of the fire is uniform in every direction. In the contrary case, those portions which, having become carbonized earliest, are kept on burning until the carbonization of the rest is complete, lose a more or less considerable portion of their carbon. Gradual burning, and especially slow burning at the commencement, yields not only a larger outturn, but also heavier charcoal. The number of times the covering breaks open or has to be opened to fill up hollows, and slowness or awkwardness in restoring it or in filling up the hollows, result in a very appreciable loss of carbon. To avoid such loss, the wood should, in the first instance, be packed as carefully and as closely as possible, and once the kiln is in full combustion, the chimney and, if the kiln is lighted from below, also the tunnel along the ground should be filled up tight.

5. *Time occupied in carbonization.*—It has already been said that rapid burning results in unnecessary loss of carbon and that moderately slow burning gives the largest yield. The length of time occupied in carbonization will vary between certain wide limits depending on the style and dimensions of the kiln, the size of the pieces of wood, the moisture they contain, the quality of the site, the nature of the weather, and the care with which the kiln has been built up. Small kilns, containing from 500 to 1,000 cubic feet of moderately hard, fairly well-seasoned wood, will require from 6 to 8 days. Large kilns, containing from 3,000 to 8,000 cubic feet of similar wood, will require 4 weeks in favourable, and from 5 to 6 weeks in unfavourable weather. Green wood will, in every case, take half as much time again as dry wood.

6. *The method of carbonization adopted.*—In the paraboloidal over-ground kiln the yield is generally increased by firing from below, as the wood in the chimney then takes fire more readily and completely, and the fire cone progresses more regularly and uniformly. When the chimney is lit from above, the fire does not often run down to the bottom quick enough to enable it to be refilled with wood to be carbonized. The result is that, after a little time, the small wood in the chimney is consumed to ashes, a hollow is formed, and the kiln falls in at the top. When the wood

is laid horizontally, it does not matter whether the chimney is fired from above or below, as the position of the pieces prevents them from falling in.

The yield is largest if the carbonization is effected with special apparatus, and least in an open pit.

7. *Skill and zeal of charcoal-burners.*—This is self-evident.

*General.*—We may now enter into a few general considerations. Assuming that we have used fairly well-seasoned, non-resinous, and non-oily wood, we would still have roughly 20 per cent. of moisture, 50 per cent. of the balance being carbon; so that if no carbon were lost in carbonization, the yield (a purely hypothetical one) would be 40 per cent. But actually, according to Boppe, the following losses occur:—

1. To raise the kiln to red heat, ...	1 per cent.
2. To expel the moisture, ...	5½ "
3. By loss of heat radiated, ...	1-2 "
4. Carbon carried off in combination in the various products of distillation, ...	11 "
	<hr/>
Total loss, ...	18½-19½ "

Thus the highest theoretical yield in carbon can never exceed about 21 per cent. of the weight of the wood. Adding up for mineral matter and the small quantity of oxygen and hydrogen contained in charcoal, the highest yield in charcoal we may expect is 23 per cent. This figure is completely justified by facts, for resinous or highly oily woods burnt in open kilns yield 25 per cent. by weight of charcoal, and other species only from 20 to 23 per cent.

The total shrinkage in volume may be put down at from 55 to 60 per cent. for resinous and oily woods and from 40 to 50 per cent. for other kinds.

The shrinkage in girth varies between 16 and 25 per cent., that in length amounting to only about 12 per cent. Hence the kiln will sink most when the wood is laid horizontally. The sinking will always be in excess of the figures given above, as a good deal of the charcoal breaks up, the broken pieces sliding in between those lower down.

Weighing the charcoal soon after it has been taken out of the kiln or oven always gives the outturn more accurately than measuring it, as the density of the charcoal will be different according to the wood used and the quality of the charcoal. Nevertheless, as the weighing of a light bulky article is always a slow and tedious

process, it is best to ascertain the quantity of the charcoal by measure. This is usually and most conveniently done with baskets of known capacity. If the weight also is required, it is easy enough to weigh a few basketfuls and strike a mean for the weight of one basketful.

#### SECTION V.—TESTING CHARCOAL.

Charcoal may be described in general terms as a black, more or less lustrous and porous, but fairly compact, substance, of low specific gravity, and possessing neither smell nor taste. These properties are subject to some slight modifications according to the wood from which it is made. We have already seen that the specific weight is, for all practical purposes, directly proportional to the density of the wood; the heavier the wood is, the heavier will be the charcoal. We know, too, that the weight of charcoal also depends on the dryness of the wood and the slowness of the carbonisation.

Good charcoal is black with a steel-blue metallic lustre, and has a conchoidal fracture. If the kiln has been kept burning too long, that is to say, if the wood has been allowed to burn on for some time after it has become carbonised, the charcoal assumes a deep black colour, and loses its characteristic lustre; it also becomes porous and lighter. On the other hand, if the carbonisation is incomplete, the charcoal is of a foxy-red colour, and emits a heavy smoke in burning. Good charcoal gives out a clear metallic ring when struck or when thrown together or stirred about; whereas overburnt charcoal returns a very dull clink and insufficiently burnt charcoal a deader sound even than wood. Both good charcoal and overburnt charcoal burn without smoke; but the latter emits no flame at all, takes fire almost instantaneously, and is very quickly consumed.

Charcoal possesses great power of absorbing gases; from moist air it will take up watery vapour sufficient to increase its weight from 8 to 12 per cent. It also absorbs water with avidity, taking up from 25 to 30 per cent. of its own weight in a few minutes, and from 60 to 120 per cent. in the course of only 8 hours. Hence the sale of charcoal by weight leaves much room for fraud and should never be employed.

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## CHAPTER II.—PREPARATION OF CUTCH AND KATTHA.

THESE two substances, popularly regarded as more or less identical, are really entirely distinct. The wood from which both extracts are obtained is principally the *Acacia Catechu*, although that of the very much less common *Acacia Suma* also yields them. These woods are impregnated with a mixture of catechu tannin and catechin, so that the extract contains both substances intimately mixed together, and it is cutch or kattha according to the respective proportions of these two substances present in it. Whether a tree will yield kattha or catechu is at once ascertained by cutting into the heartwood and noting the abundance or otherwise of white spots on the section; these white spots are incrustations of catechin. If the proportion of white spots is very small, cutch is the produce obtained.

The extract of both kinds is prepared in a similar manner. The heartwood is split up into thin chips with an adze. The chips are boiled for one or more hours in an earthen vessel, and the solution obtained is poured on to fresh chips and boiled over again. This process is repeated until the liquor acquires the consistency of a very thick syrup. For the preparation of kattha this syrup is boiled, still in earthen pots, until it becomes a thick paste, when it is cooled and poured off into moulds scooped out in fine dry sand. As a result of the cooling, the catechin crystallises, while the tannin, still in a state of solution, is to a great extent absorbed by the sand. Thus what is left behind is catechin with a small proportion of tannin. In Burma, where it is cutch that is prepared, the syrup is poured into iron pans, in which it is boiled down to a thick paste, this paste solidifying on cooling. Iron has such a great affinity for catechin, that the boiling in the iron pans destroys most of the catechin in the extracts.

Both the methods just described are extremely clumsy and slowly, as the dried extract often contains more than 4 per cent. of wood, while in the kattha there may be further admixture of as much as 16 per cent. of sand. If the manufacture were taken in hand in a systematic manner on scientific principles, special apparatus could be introduced, which would not only save labour, time,

and, therefore, money, but also give only the purest products in the largest quantity obtainable. Dr. Warth recommends the following process :—Shave the wood fine (about one-sixteenth of an inch thick) on a lathe, steam the shavings in special copper pans and boilers, cool the extract to precipitate the catechin, get rid of the liquid portion in a filter press, and finally dry, in vacuum pans, both the filtrate and what remains on the filter, the former yielding the tannin, the latter the catechin.

Dr. Warth has proved that catechin is very quickly decomposed when in a state of solution. Even pure catechin, dissolved in water and at once recrystallised, loses, on an average, 32 per cent. of its original weight. Dr. Warth has also shown that catechin is soluble only in hot water, whereas tannin is soluble at all temperatures ; and that whereas, when in solution by itself, catechin separates from the liquid without any delay if the solution is cooled down sufficiently, it takes days to be precipitated, under mere exposure to air, if tannin is also in solution with it. This demonstrates the necessity of shortening the process of manufacture as much as possible. Hence the necessity of steaming instead of boiling, and of the filter press and vacuum pans instead of slow precipitation and evaporation in open vessels or moulds. Bazar kattha made in Oudh, analysed by Dr. Warth, yielded on recrystallisation an average of only 36 per cent. of catechin, whereas by Dr. Warth's process the extract would be pure, or very nearly pure, catechin.

Although catechin decomposes so easily in solution, yet in its crystallised form it will keep unchanged for years. Hence the practice of selling it in the bazars in a liquid form is a bad one.

The market for both cutch and kattha being, in comparison with our forest resources, practically unlimited, there is no reason, with fairly high ruling prices, why in one and the same forest both cutch and kattha should not be made together, as suggested by Dr. Warth. By this means, all the khair trees of a coupe would be utilized, instead of, as at present in the case of kattha manufacture, only those which exhibit numerous white markings. In this way, the present enormous waste of khair trees would be stopped and the value of the khair forests at once increased two to ten-fold.

In Dr. Warth's experiments well-marked Oudh wood yielded 9 per cent. of catechin and 15 per cent. of tannin, while wood rejected by the kattha boilers contained 3·7 per cent. of catechin and 12 per cent. of tannin ; on the other hand, of the Burmese wood the unmarked variety gave only 2 per cent. of catechin and 14 per cent. of tannin, while the most conspicuously marked specimens

yielded from 5 to 6 per cent. of catechin and 14 per cent. of tannin.

The figures just quoted prove that with improved methods of manufacture every khair tree, including those at present rejected by the kattha boilers, will furnish catechin in paying quantities, while the yield of tannin, so large a proportion of which is now deliberately sacrificed by absorption in the sand, will be all saved for export to Europe.

## CHAPTER III.—DISTILLATION OF SANDALWOOD OIL.

THE distillation is effected by the wet process in temporary sheds erected in or near the forest. The still used is the ordinary Indian one consisting of three pots, *viz.*, two large ones, doing duty respectively as boiler and condenser, and a third, a small copper one, which is inverted into the mouth of the boiler and is practically the cap of the still. It is fitted with a copper or bamboo tube about 4 feet long and having a bore of about 1 inch, which carries down the vapour into the condenser. The boiler, which may be of metal or ordinary earthenware, holds about 56 lbs. of sandalwood chips with about 6 gallons of water. The sides of the boiler and cap are carefully luted together to prevent the escape of steam. On one side of the boiler is a small opening which can be stopped and through which fresh water can be added as the water inside is evaporated. The condenser is made of copper and has a capacity of about 3 gallons. Its mouth is stopped with leaves and coarse grass, and it is suspended on a forked piece of wood by its contracted neck inside a wide earthenware trough filled with cold water, which is constantly renewed. Several such stills, usually twelve, are fixed in a row over a common furnace made of mud or unburnt bricks. The furnace is actually fed from the back under each boiler, but it would be better to stoke it at one end, the opposite end serving as a chimney to draw a constant draught through.

The wood is shred into fine chips with a small sharp adze. As the condenser gradually fills with water and oil, the latter is skimmed off (twice or thrice in the 24 hours) and emptied into a cistern or narrow tank kept in a corner of the shed. Only a small quantity of oil is obtained at each skimming. The fires burn night and day, and a single charge of wood takes about 21 days to part with all its oil. The working season lasts 10 months, during which, however, owing to constant holidays and slackness on the part of the men, the boilers are charged only about nine times.

The wood of the root contains the largest quantity of oil, and is said to yield, according to its quality, from  $1\frac{1}{2}$  to 4 per cent. of its weight of oil, although European distillers have never been able to get more than 2 per cent. The sapwood is too poor in oil to be of any use.



#### CHAPTER IV.—MANUFACTURE OF THE VARIOUS PRODUCTS DERIVED FROM TURPENTINES.

EVERY turpentine consists of an essential oil and of a solid substance (colophony) in solution in the oil. By distilling the oil at a temperature of  $158^{\circ}$  C. (the boiling point of the oil), the colophony or resin is left as a residue.

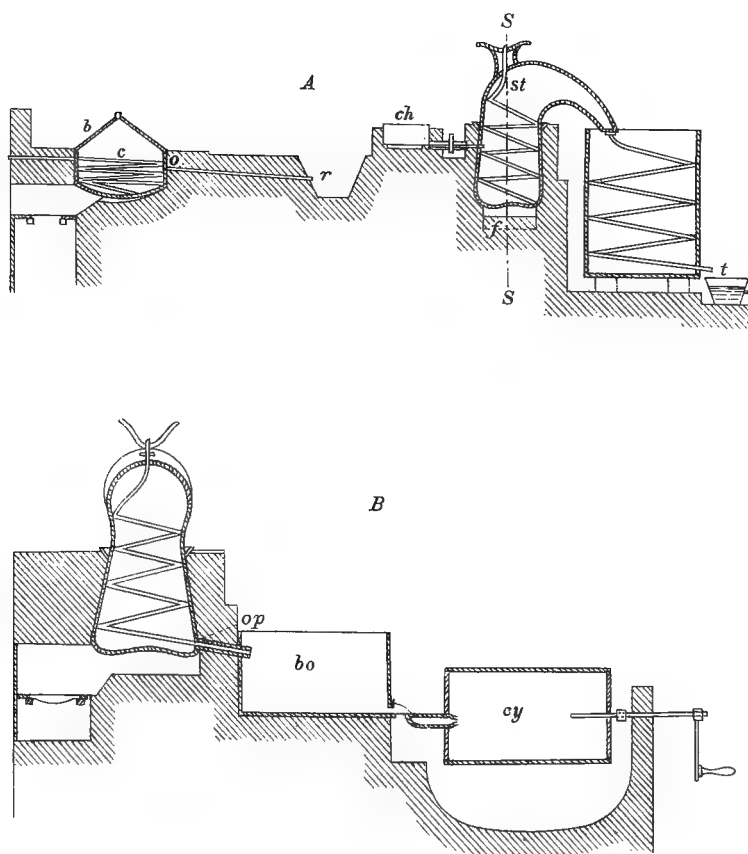
The mode of distillation followed by the natives is a very primitive one. The apparatus employed is similar to that already described in the preceding chapter. Not unfrequently no water at all is used, so that the colophony gets more or less burnt, and some acetic acid, alcohol, naphtha, and other impurities are produced and distil over with the oil.

A great improvement on this rude mode of distillation is easily effected with apparatus of almost equal simplicity and of scarcely higher cost. The crude resin should first be raised to a temperature just high enough to liquefy it, and passed through a sieve to free it from pieces of bark and other impurities. It should then be run into the boiler of a still, heat being applied, either by an ordinary furnace or a steam-jacket, until the mass attains a uniform temperature of  $100^{\circ}$  to  $158^{\circ}$ . This temperature should be continued until the accidental water contained in the oleo-resin has been driven off, together with pyroligneous acid, ether, and methylic alcohol. A thin stream of water should now be admitted, so that the temperature may be kept at or below  $158^{\circ}$ . The distillation will continue, water and turpentine oil passing over into a receiver fitted with two taps, one at the bottom, the other higher up; the water is drawn off from the former, the oil from the latter. The progress of the distillation should be judged by means of samples taken at intervals in a graduated measure. When the distillate shows only a very small percentage of oil, the still-cap should be removed, and the hot liquid rosin or colophony drawn off by a tap near the bottom of the boiler and at once run through

a fine sieve. Lastly the slight quantity of oil remaining may be driven off by heating the resin in an open pan.

There are now many improved methods of distillation, which, however, require special elaborate apparatus. One of these is represented in *Fig. 70*. The first purification of the crude oleo-

Fig. 70.



*Apparatus for distilling turpentine.*

*B is a slightly enlarged section on SS in A.*

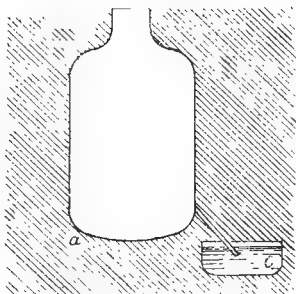
resin is effected in the boiler *b*, which has a moveable lid and through which runs a steam-coil *c*. At *o* is an orifice with a grat-

ing. All the liquefied material which reaches above *o*, runs out into the receptacle *r*, so that there remains behind in the boiler only a small quantity of resin mixed with foreign matters, such as chips of wood and bark, leaves, sand, &c. The filtered resin is transferred from *r* to a reservoir *ch*, called the charge, holding the exact quantity (about 66 gallons) for each operation. From this reservoir the resin is introduced into the still *st*. In the still a perforated worm permits of the introduction of steam when the resin, heated by the fire at *f*, has attained a temperature of 135°. Effervescence ensues and the oil separates completely from the colophony, passing over, with the steam, into the serpentine condenser, whence it falls into the tub *t*. The tub is furnished with two taps, by means of which the oil and water are drawn off separately. At the bottom of the still is an opening *op*, which is closed with a bung and carefully luted. When the oil ceases to pass into the condenser, the distilling operation is stopped and the bung removed. The colophony, at a temperature of about 130°, escapes into a box *bo*, and thence into a revolving cylinder *cy*, formed of very fine metallic gauze. The colophony falls through into a receptacle, while an unimportant residue is left inside. The oil, on passing out, is cloudy, but after standing for four to five days in large earthenware jars or copper pots, clears up, the small quantity of impurities present becoming precipitated. To prevent the solid matters in the resin from burning, the boiler *b* may be fitted with an agitator. Moreover, steam alone may be employed throughout the operation, thus avoiding all risk of burning.

There are different grades or qualities of colophony. The first exudations from new or recently freshened blazes give the best kinds, while the hard or semi-hardened concretions (*thus*, *scrape*, in French, *galipot* and *barras*, the latter being the scrapings containing *débris* of wood and bark) yield an inferior yellow resin. The lowest class is furnished by the distillation of the filtration residues left in the manufacture of the better kinds. If, while the rosin is still liquid, some water is added and the whole is briskly agitated, opaque rosin is obtained owing to the formation of abietic acid.

The pitches are produced either by a further distillation of the tar obtained in the dry distillation of highly resinous wood or by the distillation of the filtration residues left in the various processes followed for separating the oil from the colophony. In the more primitive of these processes the filtration of the crude resin and colophony is effected through mats. The mats, with what is left

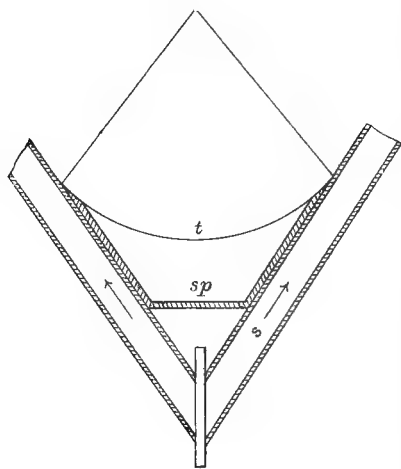
thereon, are placed in a brick furnace (*Fig. 71*). Fire is kindled at the top and the resinous matters escape into the cooler *c*, the ashes being removed through a passage existing at *a*. What passes into the cooler consists of two portions, one of them a nearly solid one, which sinks to the bottom and is black pitch. It is an opaque, black substance, with conchoidal fracture, peculiar unpleasant odour, scarcely perceptible flavour, dissolving in the same menstrua as tar, and capable of being kneaded when softened by the heat of the hand.



*Kiln for manufacture of black pitch.*

In works having the modern improvements, the only residues are those left in the boiler (*Fig. 70, b*). These residues are filtered through mats and afford a little more crude turpentine. The mats, with all the impurities, are then placed in the apparatus shown in *Fig. 72*, which consists of a double-lined trough, with steam circulating in the intermediate space *s s*. The residues are put on the metallic gauze tray *t*, and the trough is covered to prevent evaporation of the essential oil. Under the influence of the heat, the turpentine falls into the space *s p* below. It is then distilled in the apparatus represented in *Fig. 70*, and yields a light-coloured pitch, with a little oil. The straw mats are finally treated as in the preceding case and afford black pitch. From the light-coloured pitches is manufactured the common yellow rosin, which is used for sizing the inferior kinds of paper, in soldering metals, and for rendering chips of wood combustible for lighting fires. The pitch used for caulking is one of the light-coloured kinds, but may

*Fig. 72.*



*Apparatus for clearing filtration residues in making light-coloured pitches.*

be specially prepared by melting together, in certain proportions, colophony, black pitch, and tar.

The better kinds of colophony are used principally in the manufacture of paper, of soap, of sealing wax, of varnishes and of cements, and in the preparation of ointments. The different purposes served by oil of turpentine are too well known to need mention. The cleaner *scrape* (*galipot*) enters directly into the composition of certain varnishes, and is largely employed in the dockyards for painting over masts and the sides of ships.

Filtered crude turpentine is used in making varnishes, lithographic ink, and sealing wax. In France this filtered turpentine is called *pâte de térébenthine*, and is of three grades. The first is nothing but the purest portion of the crude filtered oleo-resin before distillation; the second is the filtrate obtained by exposing the crude oleo-resin to nothing stronger than the heat of the sun; while in obtaining the third, or best kind, only the ordinary temperature of the air is employed. The price of this last kind is at least six times higher than that of the other two kinds; but the yield of it is proportionately very small.

All the refuse of manufacture of the preceding articles may be burnt in closed chambers to produce lampblack. Lastly, if the crude turpentine is obtainable in sufficient abundance and at low rates, gas for lighting purposes may be manufactured from it.

## CHAPTER V.—IMPREGNATION OF TIMBER WITH ANTISEPTIC SUBSTANCES.

WHEN durable timber is not obtainable in adequate quantity and at sufficiently low rates, inferior kinds have of course to be used. In that case, their durability may be increased by impregnating them with an antiseptic substance, that is to say, with a substance that opposes decay and the attacks of insects.

### SECTION I.—THE VARIOUS ANTISEPTIC SUBSTANCES USED.

A great many kinds have been tried, but those most generally in use are—

(1). *Sulphate of copper*.—The cheapness and abundance of this substance and the ease with which wood can be impregnated with it are greatly in its favour ; but it makes the wood brittle and less resisting to strains, and as it never combines with the wood fibre, but is merely deposited in the interstices of the wood in the shape of crystals which are readily soluble, it ultimately gets washed out when the wood is placed in situations in which it is exposed to heavy rain or an overflow of water. Its employment can, therefore, never become general, and actually its use is confined almost solely to a few railway lines in France, the country of its origin, where beech sleepers are often thus impregnated.

(2). *Creosote*.—This is the creosote of commerce, and is really tar oil containing a certain proportion of creosote. It is a substance obtained in great abundance from coal, and is cheap enough in coal-producing countries. Immediately after impregnation the wood is quite soft, but it soon blackens and becomes harder, but rather more brittle, than it was before. The creosote is absorbed into the substance of the wood-fibres, of which it therefore becomes an integral part, and it can hence never be washed out. Its oily nature renders the wood more or less damp-proof, so that it diminishes the tendency of the wood to warp and split.

(3). *Chloride of zinc*.—This is a cheap substance and is very effective against decay, but does not come anywhere near creosote in practical utility.

(4). *Chloride of mercury* (corrosive sublimate).—The use of this substance for impregnating wood was first made by an Englishman named Kyan, whence the name of *Kyanizing* for the process invented by him. Corrosive sublimate is thoroughly effective against every kind of decay and insects, but its violently-poisonous nature and its high cost are against its employment.

(5). *Carbolic acid*.—This is used either by itself or in mixture with other substances, but is too expensive for ordinary employment.

(6). *Tar oil, paraffin, benzene, and other carbo-hydrates, derived from the dry distillation of coal and wood*.—These substances are injected in combination with steam, but their use has not yet become general.

(7). *Ferric tannate*.—This is a compound of iron and tannic acid. It is perfectly insoluble, and hence, when it once gets inside the wood, nothing will remove it. By closing the pores of the wood into which it is injected, it effectually keeps out moisture. As the salt is insoluble, the wood is first injected with tannic acid and then with ferrous oxide, or, which comes to the same thing and is very much cheaper, pyrolignite of iron. The two substances combine in the wood to form the ferric tannate.

## SECTION II.—METHODS OF IMPREGNATION.

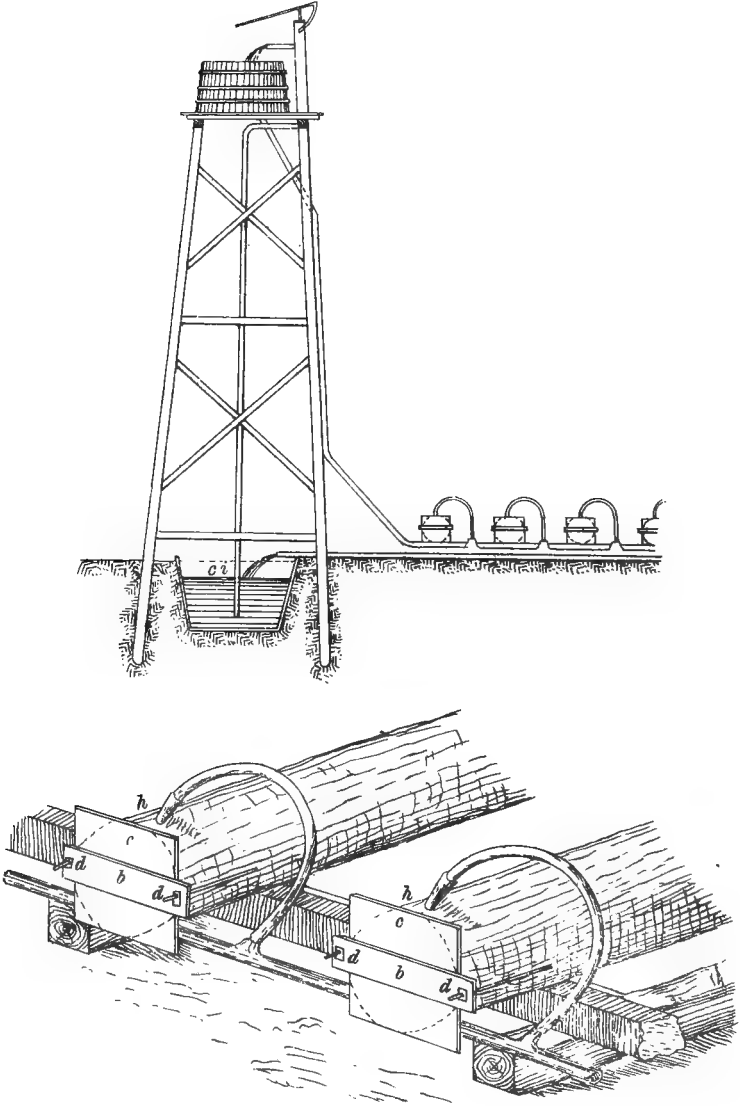
Impregnation may be effected either (1) by hydrostatic pressure, or (2) by pneumatic pressure, or (3) by immersion, or (4) by painting the surface of the wood.

### ARTICLE 1.—THE HYDROSTATIC METHOD.

By this method, which was the first one ever used and was invented by a French Doctor named Boucherie, wood can be impregnated only while it is still quite green. The sap of the green wood is driven out by the antiseptic liquid, which is placed at a sufficient height to exert a pressure of about one atmosphere. The wood to be impregnated must not be barked, otherwise much of the antiseptic fluid would escape at the sides and the entrance of air would interfere with the free run of the liquid. The pieces are generally placed with the thicker end slightly raised above the

other. *Fig. 73* shows clearly how the impregnation is effected.

*Fig. 73.*



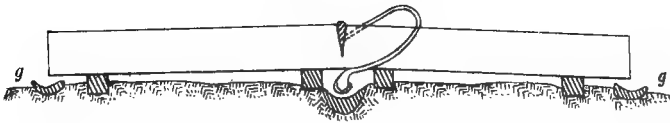
*Boucherie's apparatus for impregnating timber.*



The raised end of the log is sawn off with a clean section and covered with the cap (*c*), which consists of a square board and a ring of tarred rope placed between it and the log. The cap is pressed up against the log by the dog-bolts *dd*, the free ends of which pass through the batten *b* and are fitted with screw nuts. An oblique hole (*h*) is bored, into which is inserted the nozzle of a gutta-percha tube connected with the elevated reservoir of antiseptic liquid. The reservoir is placed about 30 feet above the ground in order to secure the required pressure of one atmosphere. Under this pressure the liquid drives before it the sap in the wood. At first, the pure sap runs out at the other end of the log in a continuous trickling stream. Later on, the sap is mixed with the antiseptic substance, the proportion of which of course increases as the sap remaining in the log diminishes, until no more sap is left and only water containing the antiseptic substance oozes out. To ascertain whether the wood is sufficiently impregnated, chips are removed from it from time to time and examined. The impregnation is complete before the liquid that runs out of the log is of the same strength as the solution in the reservoir.

The process is very considerably shortened by impregnating at once logs of double the required length. In this case the log is sawn through the middle for about three-quarters of its thickness. It is then raised in the middle so as to make the cut gape open and a piece of tarred rope is let in along the circumference. On letting go the log, the sides of the cut close tightly upon the rope, and form with it a completely water-tight chamber. A single oblique hole with inserted tube suffices to impregnate both halves of the long log. *Fig. 74* renders the preceding explanation clear.

Fig. 74.



*Mode of impregnating two lengths of log in a single operation.*

To prevent waste of the antiseptic substance, the fluid that runs out from the free ends of the logs falls into gutters *g*, whence it flows away into the cistern *ci* at the bottom of the platform. From this, the liquid, after being made up again to full strength and, if necessary, freed from organic matters, is pumped up into the re-

servoir above. The timber-yard is accordingly intersected with a well-devised system of masonry or asphalte gutters.

The substances injected in this manner are principally sulphate of copper and chloride of zinc. The strength of the sulphate solution is 1 of salt to 100 of water.

One important advantage of the hydrostatic method is that it involves only a very small capital outlay and requires no special mechanical skill to work. On the other hand, it has two disadvantages, which are great enough to militate against its general adoption. In the first place, wood in the round has to be used, so that all the portions (at least 30 per cent.), which fall off in conversion, are wasted, and thus a very large proportion of the antiseptic substance is lost. In the second place, as the wood must be green and also have its bark on, no conversion in the forest is possible, and thus cost of carriage is made a very heavy item.

#### ARTICLE 2.—THE PNEUMATIC METHOD.

This method is of English origin. The wood, fully converted, and seasoned or unseasoned (the former the better), is placed in an air-tight chamber. This chamber is completely exhausted with an air-pump, an operation which draws off all the moisture from the wood. This result is aided either by heating the chamber or by filling it, previous to working the air-pump, with steam raised to a temperature of  $112\frac{1}{2}^{\circ}$  C. and then condensing the steam to form a vacuum. Into the exhausted chamber the antiseptic solution is allowed to flow in, and, with the aid of a forcing pump, the pressure of the liquid is raised to that of nearly seven atmospheres. At the end of from 45 to 75 minutes the impregnation is complete. The liquid filling the chamber is then drawn off through a pipe at the bottom, and the chamber is opened and the wood taken out.

The substances injected in this way are creosote, chloride of zinc, sulphate of copper, tar, and ferric tannate. Carbolic acid, added in small proportions, increases the effectiveness of chloride of zinc. Creosote is the substance most largely injected by the pneumatic method. In using it the temperature in the chamber is raised to  $130^{\circ}$  C., and in order that the wood may become perfectly dry, it is kept inside the chamber for about two days before the creosote is let in. The chamber is large enough to hold several tons of wood, and the wood is brought into it on trucks moved on rails.

Another form of the pneumatic method, which is daily gaining on public favour, consists in injecting steam saturated with the

antiseptic substance, instead of using a liquid solution. The wood in the chamber remains exposed to the vapour during 6 to 20 hours.

The pneumatic method possesses advantages which render it the most practical of all those yet invented. There is no waste of wood in it, and the wood may be in any condition of seasoning. On the other hand, it requires very expensive plant, which places its adoption beyond the reach of small capitalists.

#### ARTICLE 3.—THE IMMERSION METHOD.

This method is the simplest of all. The wood, after it has been thoroughly seasoned, is plunged into a bath containing the antiseptic substance.

The more prolonged the immersion is, the more fully does the wood become impregnated, and hence the more durable does it become; but it has been found that very long immersion has the effect of rendering the wood brittle, and 24 hours are considered sufficient. No portion of the wood should be allowed to remain outside the liquid, so that light wood must be sufficiently weighted to remain below the surface. The higher the temperature of the liquid is, the more rapid and effective is the impregnation. Small pieces of timber may be boiled in the bath.

The substances experimented with in this method are chloride of zinc, sulphate of copper, creosote, sulphate of iron, and tar. The first three, being poisonous, cannot come into general use. The strength of the sulphate of iron solution employed is 15 parts of sulphate to 100 of water. Tar has to be maintained at a temperature of 143° C. during the immersion. Except in the case of thin pieces of timber, or when immersion is prolonged beyond the usual duration, the antiseptic substance seldom penetrates into every portion of the tissues, and at any rate does not penetrate equally everywhere. This is, however, not always a drawback, as impregnation of merely the outside tissues will generally suffice to prevent fungoid growth finding an entrance into the interior.

#### ARTICLE 4.—PAINTING OVER THE SURFACE OF THE WOOD.

Oily and resinous substances in a liquefied condition, if brushed thickly over the surface, enter into and fill up sufficiently the outer tissue to increase very considerably the durability of timber, provided cracks extending beyond the impregnated shell do not form. Timber used under complete exposure to atmospheric influences is tarred with excellent results.















