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Forest Utilization.

TO THE READER.

The Biltmore Forest School has offered annually, since 1898, a course of lectures on Forest Utilization—a vast topic comprising every art, every industry, all activity connected with the utilization of our woods.

If forestry is and means a business, then it is safe to say that forest utilization comprises the major—the by far major—part of the American forester's activity, provided that the term "forester" describes a man placed in charge of a forest and of its administration.

There cannot be any doubt that American forest utilization is conducted on the grandest, most ingenious scale which the world ever knew. The conditions surrounding and bearing it are entirely at variance from those now confronting the European forester. It is not to be wondered at, consequently, that little knowledge of American forest utilization can be gathered from European handbooks on European forest utilization or from European travels.

Like all disciplines of forestry, forest utilization had best be studied in and near the woods. Lectures delivered at a forest school, unless they be continuously illustrated by object lessons in the forest and in the workshop, can merely lay a bare foundation of the topic in the mind, or rather in the memory of the student.

The pages herewith submitted are printed primarily for the use of the students attending the Biltmore Forest School; they comprise the dictation given by the teacher during and after lectures; they are a skeleton of lectures merely, and it is the teacher's task to clothe the skeleton with flesh, obtained from his practical experience in the American woods.

There is ample reason to believe that one-sided and local experience has allowed a number of mistakes to creep into the following paragraphs. The Biltmore Forest School begs to be corrected by the reader, and any suggestions relative to errors and erroneous statements contained in this little publication will be most thankfully received.

Aside from the entire literature on forest utilization available in America and abroad, liberal use has been made of communications appearing in all of the leading trade papers; of the catalogues issued by the leading firms manufacturing implements for forest utilization; of the experience of the rangers and foremen of the Biltmore Estate; of information privately obtained through correspondence.

Most truly,

C. A. SCHENCK, Ph.D.,
Director Biltmore Forest School and Forester to the Biltmore Estate.

BILTMORE, N. C., Sept. 1, 1904.

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Forest Utilization.

FOREST UTILIZATION.

§ I. DEFINITION.

The term "forest utilization" comprises all acts by which forests—the immobile produce of nature—are converted into movable goods or commodities. Considered as a science or as an art, forest utilization constitutes the major part of forestry now practiced in our new country, abounding in forests.

As a discipline, forest utilization may be divided into two main parts, namely: "logging operations" and "manufacture," arranged in the following five chapters:

Chapter I. Labor employed in the forest.
Chapter II. Cutting operations.
Chapter III. Transportation.
Chapter IV. Foundations of manufacture.
Chapter V. Manufacturing industries.

§ II. LITERATURE.

There exists, unfortunately, no handbook on American forest utilization, although forest utilization shows a higher development in the United States than in any other country.

Among the foreign literature on forest utilization, publications of the following authors are particularly worthy of note:

Carl Gayer, Richard Hess, William Schlich, Hermann Stoetzer, Carl Grebe, Wilhelm Franz Exner, Carl Schuberg, Heinrich Semler, H. von Noerdlinger, Carl Dotzel, E. E. Fernandez, L. Boppe, M. Powis Bale.

Part I. Logging Operations.

CHAPTER I. LABOR EMPLOYED IN THE FOREST.

§ III. MANUAL LABOR.

A. Duration of employment.

I. Determining factors are:

(a) Climatic conditions;

(b) Economic conditions;

(c) Local custom.

In the South, work lasts all the year round.

In the Lake States and in New England, late fall, winter and early spring (from four to eight months) comprise the usual period of activity.

In the European mountains, logging is restricted to the summer months; in the European lowlands, to the winter months.

II. Advisability of continuous employment in conservative forestry, especially in the case of foremen and sub-foremen, leads to the adoption of means tending to attach the laborer to his job and to his employer.

Such means are:

(a) Advances for tools.

(b) Rent of cabins and farms at reduced rates.

(c) Help in case of sickness and accidents.

(d) Wholesale purchase of victuals so as to give the workmen the benefit of a reduced price.

(e) Firewood, forest pasture and forest litter free of charge.

(f) Permission of agricultural use, for a number of years, of clear cut areas. (This last system is called in India "tongya.")

(g) Employment during the season when cutting is stopped, in road building, fire patrol, planting, weeding, nursery work etc.

(h) Possibility for hands to rise to a foreman's position.

(i) Encouragement of home industries so as to keep the workmen busy on rainy or cold days, i. e., basket weaving, shingle making, wood carving, sieve making.

It seems most important to supply the family of the woodworker with a comfortable home and school and church advantages.

B. Remuneration.

I. Means of remuneration.

(a) Money. Wages in the South are from 50 to 75 cents a day. At Biltmore, now $1 per day, even in the mountains. On the Pacific coast, $2 to $3 per day. In Lake States, $18 to $32 per month, plus board; dry days only included.

(b) Commissary bills. This method of payment is used in the South only, in connection with colored labor.

(c) Privileges (house, farm, pasture).

(d) Board. Expense at Biltmore, per capita, 25c to 30c; in Lake States, 40c to 50c per day. Wages of camp cooks in Lake States, $50 and over per month; at Biltmore, $15 to $30 per month.

Victuals required per capita, see "Lumber and Log Book," page 144.

II. Scale of remuneration.

Wages depend on the effect of labor or on the values created by labor.

Influencing factors are:

(a) Density of population.

(b) Human strength and technical skill required.

(c) Silvicultural understanding required.

(d) Hardships endured and risks taken.

(e) Prices of the necessary victuals.

(f) Length of day during cutting season. Compare page 162, "Lumber and Log Book."

Where contract work prevails, the following additional factors come into play:

(g) Tools supplied by employer or employee.

(h) Softwoods or hardwoods.

(i) Amount to be cut per acre.

(j) Configuration of ground and remoteness from roads.

(k) Distance from home village.

(l) Possibility of continuing work during rain.

Experiments have shown that workmen paid under contract per one thousand feet b. m. earn more money in big timber than in small timber, and that a system of payment according to the diameter of the log is far more just.

C. Method of employment.

In France the woodworkers are employed by the purchaser of stumpage; in Germany, invariably by the owner of the forest. In America, both systems are found, the former prevailing. Whether the German or French system is preferable is an open question.

I. Hands are usually recruited from farm laborers, hence advisability of locally combining agriculture and forestry. In addition, the employees of the building trades, unoccupied during winter, supply help for the lumber camp.

II. Day work is advisable in preference to contract work

(a) Where quality (effect) of labor cannot be controlled, notably in nursery work;

(b) Where experienced hands must be trained;

(c) Where contract labor cannot be obtained (Pacific coast);

(d) Where contract legislation is bad. (Lien laws in Minnesota; $1,500 exemption clause in North Carolina.)

III. Contract work is generally preferable to day work because it is cheaper. Contract work is doubly advisable where employer's liability laws work against the employer. Contracts should always be in writing. The specification sheet should be kept apart from the paragraphs of agreement, so as not to encumber the contract.

The main clauses of a contract cover:

(a) Time allowed to complete work;
(b) Installments and payments;
(c) Building of snaking roads, sleigh roads and skidways;
(d) Scaling of defective logs and of sound logs;
(e) Employer's liability;
(f) Fines for fire, stock at large, fishing, hunting and drunkenness, and demand for discharge of culprits;
(g) Shanties and log houses and commissary bills;
(h) Supply of tools; deduction for loss and spoliation of tools;
(i) Fines for cutting trees not marked or of too small a diameter;
(j) Fines for leaving marked trees uncut;
(k) Fines for poor work and unnecessary damage;
(l) Possibility of speedy termination of contract in emergency cases;
(m) Nomination of umpire to avoid suits in case of discrepancies.

The specifications cover the following points:

Height of stumps; peeling of bark; separating product according to quality; length, diameter, weight of product; nosing logs; cutting defects out (unsound knots etc.); placing the product on sticks (so as to allow it to dry) or on skidways; method of carrying or moving products; swamping (removal of branches); use of road poles (breast works); skidways; road building.

D. Subdivision of labor.

The leading principle is that one division gang must push the other.

I. Lumbering.

(a) Cutting or felling crews, consisting usually of two hands; sometimes a third man to drive wedges and to make the axe cut.
(b) Log makers, dissecting the bole into logs. A foreman should be an ex-sawyer or an ex-lumber inspector.
(c) Swamping crew, to clear trees of branches and to open suspicious knots.
(d) Snaking crew—at Biltmore five hands for a three-yoke team; three men to get the logs ready and to remove brush (debris) and two men to accompany the load.
(e) Skidway crew—two hands rolling logs onto skidways.

(f) Road crew—meant to prepare snaking or sleigh roads; to sprinkle and sand ice roads.

II. Firewood or cordwood making (for pulp, distillation, cooperage etc.).

a, b, and c are the same as in "I.—a, b and c."

(d) Carriers or carrying crew—often with hand sleighs or rollers or grapple hooks.

(e) Splitters—with heavy axes which have broader, thicker cheeks than cutting axes.

(f) Piling crew—a very careful, honest man is required for piling the wood.

§ IV. ANIMAL LABOR.

A. Countries.

In Europe, even in virgin forests, practically none is required. In India and possibly in the Philippines, elephants are used.

In the United States, in the Southern and Pacific States, as also in the Appalachians, oxen are used. In the Lake States, Pacific States and New England States, horses are preferred. In the South, mules are used for small logs and especially on tram roads.

B. Horses.

I. The numerical ratio between hands and horses in Northern camps varies from 2 to 1 to 6 to 1.

The standard amount of work for one horse is:

(a) A haul of 1,600 lbs. inclusive of wagon, on a level road over 23 miles per day.

(b) An output of 2/3 horsepower per minute, equal to 320 horsepower per day of eight hours.

II. Horses are employed for

(a) Skidding or snaking.

(b) Rolling logs on skidways.

(c) Sleighing, trucking (two wheels) and wagoning (four wheels).

(d) Go-deviling.

(e) Loading on railroad cars.

(f) Supplying power for portable mills.

III. Food for horses.

(a) Interdependence between feed and effect in foot pounds per 1,000 lbs. horse flesh during a day's work is:

Straw	2 lbs.	2 lbs.	2 lbs.
Hay	19 lbs.	15 lbs.	11 lbs.
Oats	2 lbs.	6 lbs.	10 lbs.
Effect	3,000,000	9,000,000	15,000,000

(b) Food required.

After Thaer, per 1,000 lbs. of horse flesh, 25 lbs. of good hay and oats.

After the "Lumber and Log Book," 50 lbs. of oats and 40 lbs. of hay per team per day.

(c) Feed values equivalent to 100 lbs. of good hay, after Haswell, are
= 54 lbs. of barley.
= 57 lbs. of oats.
= 59 lbs. of corn.
= 275 lbs. of green corn.
= 374 lbs. of wheat straw.
= 400 lbs. of cornstalks.

C. Mules.

I. They are employed for:
(a) Light logs on good ground and for long distances.
(b) For wagoning lumber and provisions.
(c) For hauling on rail tracks (wooden and iron rails).
(d) For hoisting logs on inclines.
(e) For plowing and scraping in road and railroad building.

II. Food for 1,000 lbs. mule flesh, as for horses.

Mules require less care than horses, taking care of themselves and resisting overwork. They are frequently not fed at noon. (Price per team at Biltmore, $200.)

D. Oxen.

I. Price per yoke is from $80 to $120, weight from 2,000 to 2,500 lbs.

Ox yokes form the rule, although efficiency of oxen in harness is superior. Shoeing for each claw separately—difficult and risky, but necessary on hard ground.

Special training takes place from second year on. Fitness for hard work begins in the fifth year, when ossification of bones is completed.

Special training for leaders.

II. Employment.

In the South for snaking heavy logs—or log trains in Oregon; for hauling logs suspended underneath high two-wheel trucks in the pineries; rarely for loading cars or wagons.

III. Standard work.

An ox walks 14 miles per day with load. An ox yields in eight hours of work 270 horsepower, hence he produces only four-fifths of the effect of a horse.

After Thaer, an ox produces only one-half as much power as a horse of the same weight.

IV. Feed.

(a) It is much cheaper to feed oxen per 1,000 lbs. living weight than to feed horses of same weight.

Ruminants have four stomachs and thus digest their food better. No feed is given in the middle of the day, and no expense is incurred during idle periods, where pasture is available.

(b) Careful treatment and good stables required. Oxen must not be hurried. Soft yokes, proper salting and regular watering.

(c) In the South, at the present time, cottonseed meal and hulls form the cheapest food. Food requirements per yoke per day are 25 lbs. of meal and 40 lbs. of hulls. Present prices of meal $25 per ton and hulls $8 per ton, delivered at Brevard, N. C.

CHAPTER II. CUTTING OPERATIONS.

§ V. WOODSMEN'S TOOLS AND IMPLEMENTS.

A. Axe. It consists of a handle, 32 inches to 42 inches long, made of hickory, ash, locust or mulberry, either straight or "S" curved, and of a blade or head forming a steel wedge of particular temper. The cheeks of the wedge are slightly curved in the midst, falling down gradually towards the upper and lower line. The weight lies either close to the bit or close to the handle, according to local predilection.

The best make is the Kelly axe.

Double bit axes, requiring straight handles, are largely used in the Northeast. Special splitting axes, of greater weight and broader cheeks, are rarely used (for sugar barrel bolts and retort wood).

For hardwood, a thin and light axe (a cutting axe) is preferred, while for softwood a broad and heavy axe is used (a tearing axe).

A box of axes contains an assortment of various weights. In Europe the bit is relaid with steel, after wearing off.

The axe is used

I. For cutting trees entirely or partly.
II. For swamping (axe to be ½ lb. heavier).
III. For splitting.
IV. For nosing logs.
V. For driving wedges.

Price of axes from $6 to $8 a dozen. Handles are $1 a dozen.

B. Adz and broadaxe.

The adz and broadaxe are used for trimming and barking export logs, squares, ties and construction timber. The blade of the adz stands at right angles to the plane of the sweep and has such curvature as corresponds to the curve of the sweep through the air. The cutting edge is ground concave on the inner side.

The broadaxe is either right or left sided, the plane of the blade forming an angle of 5° to 10° with the plane of the handle. The handle is usually short, the blade very heavy and wide.

C. Peavies.

The peavy is a typical American tool, not used elsewhere. The best make is Morley Bros.' line of blue tools.

The hooks are distinguished as round bill, duck bill and chisel bill hooks, made of hammered steel. The socket is either solid or consists of rings. The square pick (point) is driven cold into the round bored point of the handle. The handle is 4 to 6 ft. long, straight, 2½ inches to 3 inches through and is made of hickory, ash, or usually hard maple. Price per dozen is $10 to $22.

A peavy must answer the following requirements:

I. Hook adapted to any size log.

II. Bill to be so constructed as to catch securely through any layer of bark.

III. Proper length, greatest strength and low weight.

D. Cant hooks.

The cant hook is a peavy, lacking the pick (point).

The socket consists of two rings only joined by a narrow bar.

Cant hooks are used more in the mill and yard, peavies more in the woods.

E. Cross-cut saws.

I. Radius experiments show a radius of 5 feet 2 inches to be best. The straight drag saws require excessive strength and are deficient in dust chambers.

II. Width of blade.

It is at the widest point about 8½ inches. The hollow back saws, a very recent invention, have only about 4 inches width all through.

III. Thickness of blade.

The back of the saw is always somewhat thinner than the gauge of the teeth. Henry Disston gives the saw backs 4 or 5 gauges less thickness than the saw teeth. Atkins gives the teeth "14 gauge," the back at the handles "16 gauge" and at the center of the back "19 gauge."

IV. Uniformity of temper and proper temper are obtained by special processes. No hammering of blades. Cheeks are perfectly smooth.

V. Construction of teeth is very variable. Dust room between the teeth should be twice as large as the teeth.

For hardwoods more teeth are necessary than for softwoods.

There are two kinds of teeth, namely:

(a) The cutting teeth, a couple or trio of which might be arranged on a common stock, to form "Tuttle or Wolf Teeth." Only the points of the cutters actually cut into the fibre.

(b) The raker or cleaner teeth, meant to plane off the fibre severed by the cutters and to shift the sawdust out of the kerf. European experiments prove the uselessness of cleaners. They simply occupy valuable dust room. The point of the rakers should recede by 1/32 of an inch from the cutting line of the cutting points.

VI. Length of saw is from 4 ft. to 8 ft. At Biltmore 6½ ft. and at Pisgah 7 ft. is preferred.

Local crews use the "diamond cross-cut," the "champion teeth" and the "hollow back" saw.

VII. Saw handles should be easily detachable. The material of the handle is maple, birch and hickory. Handles are fixed (usually) vertically to back of saw. Sometimes, however, they are in the direction of the radius of the saw.

Large "bow" saws allow of a very thin blade and have a bow instead of handles. They are not used in America.

VIII. The effect of a saw is equal to the number of square inches cut by one man per minute. The effect is small in polewoods, increasing gradually up to a diameter of 1¾ ft. and decreasing thereafter owing to increasing friction.

In cutting longleaf pine, the saw is continuously sprinkled with turpentine.

The effect of curved saws is from 40% to 50% higher than the effect of straight saws.

The saw overcomes

(a) The resistance of the fibre by the sharp points acting as knives and planes;

(b) The friction at both cheeks of the blade by smooth cheeks and by a gauge narrowing toward the back;

(c) The friction of sawdust by deep teeth, curved line of teeth, perforation, large dust chambers and possibly by "cleaning teeth."

IX. Dressing of cross-cut saws.

(a) "Jointing" means filing all cutting teeth down to exactly the same circumference.

The tool used is called a jointer. A file is placed in the joints and by a screw pressed into the proper curvature.

(b) "Fixing the rakers" means filing them down with the help of a raker gauge. The rakers act as brakes if they project into the cutting line. Outside and forks of rakers are slightly filed to remove case hardening, and the point is sharpened to a planer edge.

A raker swage is being introduced to spread the points of the rakers and to give them a hook-like point, which is said to tear out long slivers instead of tearing out dust.

(c) "Setting the cutter teeth" is done under the control of a "set gauge" with the help of a "set block and hammer," giving 3 to 4 taps (the best method when done by experienced men) or with the help of a "saw set." "Saw sets" are constructed either wrench-like or after the hammer and block principle.

Rules of setting are:

1. Setting should never go lower than half the length of the tooth.
2. It should never exceed twice the gauge of the teeth.

3. More set is required for long saws and for soft woods than for short saws and hard woods.
4. When hammering, strike tooth fully ¼ inch from point of tooth.
5. If teeth are badly set, take, to begin with, all set out of the teeth.
6. Apply side file inside file holder, to take away slight irregularities of set (after filing the teeth).

(d) "Filing." Filing usually follows setting except in the case of saws spanned in a vise, when the set is afterward given by holding the set block on one side of the spanned saw and hammering from the other.

Rules of filing are:

1. File inside of tooth only.
2. File to a bevel or fleam of 45°.
3. Push the file away and do not draw it toward you.
4. Do not file point to a feather edge.
5. It is useless to sharpen tooth below the cutting point.

(e) "Gumming." Gumming is usually done with the file; the lever (punch) gummer may be used for the purpose, however.

(f) Remarks: A good, well-tempered saw holds sharpening and filing for six work days.

In California one man "cross-cut saws" up to six feet long are used in dissecting the bole into logs.

The cross-cut saw file shows, on the cross section, a narrow triangle with curved back.

In Europe flat and triangular files are used for cross-cut saws.

The "spread set" of the cutting teeth has been tried and was found impracticable.

F. Wedges.

Wedges are used:

I. To split wood. The "axe wedge" is usually made of iron and should have straight and not convex cheeks, which are often grooved to prevent wedge from jumping the cleft.

Wedges are sold by the pound.

Iron wedges are prevented from jumping by heating them, by putting dirt in the cleft, or else a rag (wet) over the wedge.

Wooden wedges are made of the butts of hard maple, hornbeam, black gum, dogwood and beech.

Iron wedges with wooden backs are frequently used abroad.

II. To prevent saw from pinching in the kerf.

Special saw wedges of oil-tempered steel are made by Morley Bros.

Frequently saw wedges and axe wedges are used alike.

Wooden wedges must be driven with the axe or hammer.

Iron and steel wedges must be driven with a wooden maul.

G. Mauls and maul bands.

Mauls are made of the butts of dogwood, beech, hornbeam, hard maple, gum and locust, and are held together by two iron hoops made of ½-inch by ¾-inch flat iron.

H. Pickaxe and mattock.

They are used where the stumps are used together with the bole and in the preparation of forest roads. The points of both are relaid with steel after wearing out.

I. Brush hooks.

They are used in cleaning boles and in making fagots or fascines; further in clearing snaking roads in dense underbrush.

J. The krempe.

The krempe is used largely abroad and in India and resembles the picaroon or hookaroon used in America for handling ties, telegraph poles and pulp wood. It is used in rolling and moving logs down hill, the pick acting as a lever, the fulcrum of which lies at the heel.

K. Pike poles.

Pike poles are used with pike and hook or with pike only; are 12 ft. to 20 ft. long, made of selected white ash, the points consisting of cast steel. The points are either screwed into the wood or driven without heating. Pike poles cost $10 to $25 a dozen. They are indispensable in driving and rafting operations and at mill ponds.

L. Screws for blasting stumps. Such screws are used abroad, not to shoot stumps out of the ground but solely to split stumps where prices of firewood are high. The hollow screw loaded with blasting powder is inserted into an auger-made hole.

M. Grindstones.

Grindstones should not be exposed to the sun, should be kept equally round and even and should always be kept wet while in use. A water trough underneath the stone should be rejected, as the submerged side softens unduly and unevenly. Stones are sold by the pound.

A 70-lb. grindstone costs about $4. The extra fixtures, consisting of hubs, shafts with nuts, crank etc. cost about a dollar.

N. Machine saws.

For cutting trees such saws have proven a failure. Similar was the fate of the "electric cutting machine" recently patented by Bayer. The expense of carrying machines from tree to tree is greater than the expense of cutting by hand.

O. Tree-felling machines.

They are largely used abroad to obtain the stump of a tree together with the bole.

I. One of them is the "Nassau machine," consisting of a 4-inch board 10 inches wide into which regular steps are hewn, and of a pole about 25 ft. long, with a crooked pike at the small end and squarely bound in iron at the big end. Half a foot above the big end the pole is perforated so as to receive a 1½-inch round steel spike. The square base of the pole is placed on a step of the board, fixed flat on the ground, some 12 feet from the tree. The pole then forms an angle of about 50° against the board, while the spike is securely placed into the bole of the tree. By means of two crowbars the base of the pole is moved step by step toward the tree. This machine must be used in Hesse Darmstadt, under the employer's liability law.

II. The "wood devil" has been used for centuries in Switzerland. A rope or cable is fixed in the top of the tree to be felled and a chain is fastened around a stump in the falling direction, which chain ends in two hooks. The lower end of the rope is secured to a chain, the links of which receive the hooks. By moving a long lever to and fro, the hooks are inserted alternatingly in the chain end of the rope, advancing two or three links at a time.

The instrument is very cheap, simple and powerful; at an angle of 45° the rope has the maximum of power.

III. To remove stumps alone the stump lifter might be used.

IV. "Weston's differential hoist" lifts the maximum of weight with a minimum of its own weight.

A Weston hoist capable of lifting 1½ tons 8½ ft. high weighs only 81 lbs. and costs $25.

§ VI. FELLING THE TREES.

Under "A" and "B" are described the chief methods of felling.

A. Obtaining bole without stump and roots:

I. By exclusive use of the axe, handled from one side only in cutting small trees, in thinnings and in coppice woods.

II. By exclusive use of the axe, cutting two kerfs on opposite sides. The first notch, on side toward which tree is intended to fall, made from 4 inches to 6 inches lower, must penetrate the center of the tree. Avoid felling toward the direction in which the tree leans.

Advantages of this method are the facts that one tool and one man only are required; that the bole is easily directed; that the logs obtain proper noses.

Disadvantages are loss of bole, amounting to from 4 % to 8 % and loss of time and labor in large timber. This method of felling is universally used in Maine.

III. By hewing "out of the pan," a method used for valuable heavy boles. Uncertainty of fall is counterbalanced by a gain in the length of the bole. The bole thus obtained is said to show less heart shakes.

IV. By using the two-handed cross-cut saw alone, without the help of the axe, a method not advisable for the reason that the fall of the bole cannot be directed.

V. By joint use of cross-cut saw and axe. The axe cuts a kerf on the falling side, the depth of which is 1/4 to 1/5 of the diameter, and the innermost point of which lies on a level with the saw kerf. When the saw begins to pinch, drive wedges behind the back of the saw. Withdraw the saw when the tree begins to shake heavily and force it to fall by wedging.

Advantages of this method are: the trees are easily directed at a small loss of timber.

Disadvantages are: several tools and several men are required. In very thick woods and on very rocky, steep slopes, the use of the saw is not advisable or possible. Careless wedging may cause the bole to split at the butt. The saw and the wedge are said to be responsible for heart shakes.

B. Obtaining bole with stump and roots:

It is essential to thoroughly sever the main roots with axe, mattock and pick. The tree is then forced over by a tree-felling machine, or with a rope fastened to a high limb.

Advantages are: longer bole; gain of lumber 8 % to 10 %. Possibility of obtaining knees for ship building (tamarack and white oak). The tree falls gently, its fall being checked by the roots so that the bole shows less splits, cracks and wind shakes. The bole is less apt to break and can be allowed to dry out gradually. Further, root-breeding insects don't find any incubators and agricultural use is facilitated.

Disadvantages are: greater expense, more tools, axes ruined in cutting roots, extra saw cut required to sever the butt log from the roots and, above all, the delay in finishing the logging job.

C. Criteria of a good method:

I. Danger to workmen.

II. Total net value obtained.

III. Wastefulness.

IV. Possibility of throwing the tree in the desired direction.

D. Pollarding before felling:

The branches or the tree tops in European logging are frequently lopped off before felling, for the following reasons:

I. The younger generation of trees surrounding the tree to be cut receives less injury.

II. Lopped trees touch the ground all along the bole at one and the same time. Hence no danger of the boles breaking or splitting. In addition, a reduced crown causes the tree to fall with decreased force.

E. Felling rules:

I. The trees must be thrown in such a way as to do least damage to themselves, to surrounding trees and to undergrowth.

II. The felled tree should lie in a position allowing of easy dissection of bole and of easy removal of logs.

III. Operations must be stopped during storms and blizzards.

IV. Trees over 6 inches in diameter should be sawn down, coppice woods excepted.

V. No more trees should be felled than can be worked up within reasonable time after felling.

VI. The stumps should not be higher than the tree's diameter.

VII. All trees marked for cutting, and none else, must be cut.

VIII. The tops should be swamped so that they may come in contact with the ground.

§ VII. DISSECTING THE BOLE OF THE TREE.

A. Purpose of dissection.

I. Reduction of freightage.

II. Better adaptation to different methods of transportation required for different assortments.

III. Better accommodation of buyers requiring different assortments.

IV. Obtaining manageable size of logs and wood.

As much net value should be obtained from the bole as possible. Waste is advisable wherever it pays to waste.

In no forest on earth is all the woody substance produced marketable. The amount of offal (waste, debris) depends merely on the expense of transportation to markets within nearest reach. It is better to waste wood than to waste money. The modern lumberman gathering logs of 4 inches diameter and the modern forester objecting to any waste frequently neglect this rule.

B. Factors influencing the dissection:

I. Requirements of the market governed by custom.

II. Distance from market: the longer the distance, the better must be the quality of the product.

III. Locality (f. i. steepness of slope; swampiness).

IV. Local laws (f. i. in North Carolina relative to 8-foot firewood).

V. Available means of transportation and their construction.

VI. Freight rates varying with the degree of conversion.

VII. Size of cars and wagons.

VIII. Length of mill carriage and of feedworks.

C. The main divisions of woody produce obtained from dissected boles are:

I. Piece stuff, i. e. logs, blocks, construction timber, sold by the foot, the standard, the pound.

II. Numbered stuff, i. e. poles, posts, mine props, scaffolding poles and shingles, boards and staves, sold by the dozen, by the hundred, by the thousand etc.

III. Space stuff, i. e. industrial cordwood (for insulator pins, bobbins, pulp, tannin etc.), tanbark and fuel, sold by the cord. In the case of bark, 2,240 lbs. are usually considered the equivalent of one cord.

D. The specifications governing the dissection describe:

I. The dimensions, i. e., the range of length and diameter desired for each section obtainable.

II. The quality of each section and the defects allowed and prohibited therein.

(a) Saw logs for lumber.

1. Dimensions. Douglas fir on the Pacific coast used to be cut in logs 24 ft. long. The minimum diameter permissible was 30 inches.

Spruce in New England is often cut 13 ft. 4 inches long with a diameter of 6 inches and up.

For yellow pine logs, any length and any diameter over 8 inches are permissible.

Hardwood logs have a length ranging from 6 ft. 4 inches to 18 ft. 4 inches, arranged in intervals of 2 ft. Odd lengths are scaled down. A deficiency of ¼ ft. in length of board or less is, however, often disregarded.

Export logs of yellow poplar are 8 ft. and 16 ft. long.

Jack pine logs for cheap box lumber are often cut 6 feet 6 inches long, the diameters ranging from 4 inches upward.

2. Treatment. Saw kerfs at either end of log should be made perpendicular. Branches should be swamped off, knots cut level and laid open. Bark in the case of conifers is frequently peeled off in Maine and in Europe. Bark rings are sometimes left at the ends. Defects of bole must be concentrated in one log, or must be sawn out. Nosing is required for loose driving and for snaking. Painting of end faces with red lead is prescribed for export logs. Very heavy logs are sometimes split in two. Putting logs on sticks to prevent spoliation of sap and to reduce specific gravity is often advised.

(b) Blocks for woodenware.

Poplar, for large bowls, must be entirely free from defects. White pine blocks are often cut between the whirls of branches.

(c) Hub blocks must be butt logs, the length allowing to cut either two or four out of the block.

(d) Construction timber is hewn according to local requirements. Minimum diameter at small end most important. Construction timber abroad is sometimes whip sawn.

(e) Poplar and walnut squares run from 4″ x 4″ to 10″ x 10″. They are whip sawn in the backwoods of western North Carolina.

(f) Telegraph poles. The smallest diameter, the diameter at or close to the big end, the length, crooks and treatment of bark must be considered. Sometimes pointing of the small end is specified.

(g) Fence posts. Species, length, smallest diameter, straightness, method of manufacture etc. must be considered. Usual length is 6½ feet.

(h) Railroad ties. Specifications are very variable. Face is usually from 6" x 6" to 7" x 9". Sawed railroad ties are used, especially in the yellow pine section. Great waste in hewing ties from trees just too small to yield two ties. Specifications cover allowance of sap, wind shakes, wany edge and dote.

(i) Shingle bolts. Lengths are multiples of 16" and 18", usually.

(j) Mine props. Middle diameter from 3" to 8".

(k) Stave and heading bolts. Basswood heading bolts used in Michigan. Length 18" or 37" and diameter not less than 8". If from 12" to 18", split into halves. If over 18", split into quarters. White oak bolts used at Wilmington measure 36" for stave bolts and 24" for heading bolts; core must be hewn out; minimum face at inner edge 4".

Heading bolts for sugar barrels in the Adirondacks consist of spruce cut in lengths forming multiples of 22" with a diameter minimum of 6".

Stave logs for sugar barrels consist of birch, beech and maple, the lengths forming multiples of 32", with a diameter minimum of 8".

(l) Bolts for carriage spokes. Material is black or shellbark hickory, white oak, white ash and post oak strictly free from imperfections. Minimum diameter 12"; length 6½ feet, 7½ feet, 8½ feet and so on.

(m) Paper pulp. Logs scale 6" and upwards; no dead timber. In the State of Maine pulp logs are peeled in the woods.

(n) Veneering blocks. Hardwoods preferred, of the biggest possible diameter, but certainly over 18" diameter. Blocks from 2 to 6 feet long.

(o) Tannin extract wood. Length of wood 5 feet, split from logs 10 inches and over in diameter. Wormholes allowed. Fibre must be absolutely sound. A cord consists of 160 cubic feet.

Higher price for peeled wood. Butt logs preferred. Cutting of saw logs out of same tree forbidden.

(p) Fuel cordwood. Advisability for piles to contain one cord. Weight of pieces should be such that one man can lift them easily. Splitting facilitates the process of drying; in pine wood it also prevents rotting.

CHAPTER III. TRANSPORTATION.

§ VIII. TRANSPORTATION WITHOUT VEHICLES ON LAND.

The following methods of such transportation are en vogue:

A. Carrying stove wood, pulp wood, extract wood etc. on men's shoulders, a method of transportation very largely used abroad and in India. Carrying distances abroad range up to one-eighth of a mile. In India railroad ties are carried by the Hindoos over much longer distances.

"Stretchers" are sometimes used where slope is not steep, or "timber carriers." Morley Bros.' lughooks are used in America.

At Biltmore firewood is carried to the roads over an average distance of 150 feet on men's shoulders.

B. Dragging logs by human force where vehicles or water is near and where produce does not weigh over a ton. The front end of a log is placed on a tray (lizard) to prevent it from boring into the ground.

Barked or peeled and well trimmed logs are easily dragged. Silviculturally, dragging is, of course, inferior to carrying of wood products.

C. Rolling logs by human labor is necessary almost everywhere. Peavy, cant hook and "krempe" are used for the purpose.

On a slope of about 15 %, after removing obstacles, logs will roll easily.

Shingle blocks, stovewood blocks and other short round wood may be spanned in a frame. This method of transportation badly damages young growth and trees left standing.

D. Shooting logs down chutes.

A dell in the slope of 30 % or more is often filled with (peeled) logs; then the top logs are shot down the dell over the other logs below.

Three kinds of chutes proper may be distinguished:

I. Pole chutes;

II. Board chutes;

III. Earth chutes.

I. Pole chutes have been largely used in the United States, costing about $300 a mile. They are said to last from seven to ten years and should have the following grades:

	For long logs.	For short logs.	For railroad ties.
Dry chute	15-20%	25-35%	26%
Iced chute	4- 8%	8-12%	6%
Watered chute	3- 6%	5- 8%	

Heavy curves must be avoided and the outside of light curves fixed with a number of "saddle logs."

Pole chutes consist of a trough made of four to six poles. The pole chute is about three feet wide and requires cribs or yokes for a foundation where it is not laid on the ground.

Water, ice and soap are used for lubrication. Chutes made of hardwoods are said to run smoother than those made of conifers, owing to the greater elasticity of conifers. Where the grade is light, poles should be peeled and hewn on the inside. The grade of inlet must be very steep; the outlet should open into a pond. Frequently, when the job of chuting is finished, the poles or ties composing the chute are shot down themselves, thus dissolving the chute.

II. Board chutes, which are frequently movable, consist of 1-inch or 2-inch boards. They are used in carrying firewood and other short stuff down slopes of 25% to 35%. The rougher the produce, the steeper must be the grade and the wider and smoother must be the trough. Sprinkling is required during dry weather, sanding during wet spells.

III. Earth chutes. These resemble snaking roads of a steady grade, which grade must be:

(a) Where snow or ice crust is available, 8 to 10%.

(b) Where split cross ties are used, laid about 5 feet apart; for logs 16 feet long or longer, from 10½ to 18%.

(c) Where dry earth is used, 25% and over.

Road poles must be used on the valley side, especially so in curves, and bridges must cross all the gullies.

E. "Roping" is a method employed for moving long and heavy logs in the "Black Forest." A rope is fastened at the small end of the log to a ring dog and swung once or twice around the stump of a tree nearby. The log is started by the "krempe," and its speed is controlled by loosening or tightening the loop around the tree. When the rope is run out it is fastened anew, after stopping the log, to a tree lower down on the slope. The best slope is about 35%.

F. Snaking logs or skidding logs.

I. Attachment by chains 12 to 16 feet long and 1/3 inch to ½ inch thick ending in dogs. When a chain link breaks, a "cold shut" is put in its place (cost $3 per 100 for ½-inch chain). For smaller logs skidding tongs are used in place of dogs, attached to main chain by three rings, swivel and hook, and costing, per dozen, about $50.

In the case of horses, stretchers are used to prevent the traces from hurting their legs.

On muddy soil, the nose of the log is frequently placed on a tray, or a lizard, or a triangle.

Snaking dogs are usually hand made and should be driven by a maul. Plain points on dogs seem to be preferred. Logging dogs 10 inches to 12 inches long are quoted at $15 per dozen.

II. Animals. For long distance hauling, mules or horses are preferred to oxen. Ox harness is rarely used. In the South three yokes form a "team" usually, the chains running from yoke to yoke. Leaders (oxen) require special training. The teamster manages the yokes of oxen by shouting, applying the whip as little as possible.

III. Roads for skidding or snaking.

(a) Uphill grades must be strictly avoided; even level stretches are disastrous. The grade depends on the season of usage. Where ice and snow are available 1% or 2% are ample. On dry rocky ground 50% is the maximum. On the average, for "Biltmore" conditions, 20% seems best.

(b) Curves must be strictly avoided, especially "inside curves" skirting a gully. Herein lies the greatest difficulty of snaking road building in sections where the mountain slopes are deeply gullied.

(c) In the Appalachians the surface of the road is 2½ to 3½ feet wide and road poles laid on the valley side prevent the logs from jumping the road.

Swampy and moist places are corduroyed lengthwise with the road. Creeks must be bridged. It must be kept in mind that one bad spot in a snaking road requires the use of additional teams over the entire length of road.

Regular troughs made of two strong poles resting on cross ties are used in Pennsylvania, where grade is deficient and distance long. Out West cross ties 7 feet apart are placed on the road. In both cases long log trains are formed. It is claimed for such trains that the pull or strain on the animals is evened or equalized, some logs sliding down hill while other logs of the same train overcome impediments.

(d) Means of lubrication are: Sprinkling with water; laying cross ties or length ties; peeling of logs; greasing the ties.

Means of braking the logs are: Sprinkling earth, sand, hay and branches on the road; throwing chains on the road, or tying chains around the logs.

(e) Snaking distance. Snaking distances range up to one mile (usually), averaging about one-third of a mile. Where many logs, say 30,000 board feet of logs or more, must be transported on the same road over an average distance greater than one-third of a mile, other means of transportation are usually preferable to snaking.

In the Appalachian hardwoods the expense for 1,000 board feet snaked over ½-mile amounts to about $4. In the Adirondacks skidding costs 40c to 50c per 1,000 board feet, the distances being short, since the logs are merely skidded to the skidways arranged alongside the sleigh roads.

G. Drums.

I. Hand drums or winches are used for yarding logs and especially for hoisting logs up hill on steep inclines, the distances not exceeding 300 feet. G. B. Carpenter quotes single "drum grabs," weighing 275 pounds and having 2 tons power, placed in strong oak frames, at $27. Power-capstans might be used for the same purpose.

II. Drums with horses as motive power are used in eastern Tennessee for hoisting logs up to the rim of the sandstone plateaus.

III. Steam power is now universally used out West in connection with drums known as "Bull Donkey" and "Donkey" engines. Skidding or snaking roads are usually dispensed with. Steel cable (¾-inch plow steel) is used on the drums. The distance of haulage should not exceed 1,200 feet. The main cable is pulled out by a

½-inch endless cable ("tripline") running into the district to be logged over a number of tackle blocks. Zigzags can be made by using tackle blocks on the hauling line as well. One engineer and one fireman are all the crew required in addition to two loaders. Frequently the engine loads logs on railroad cars at the same time.

The engine's cylinders are about 8 inches by 10 inches. Engines are moved from place to place by their own power. Price for an engine f. o. b. Biltmore is $1,400. Boilers are of the upright type. The wire cable is usually made of 6 strands, each containing 19 wires, wound around a hemp center. Running cables should never be galvanized. The proper load of a cable is only one-fifth of the breaking strain in tons. Steel ropes (cables) have twice the strength of charcoal iron ropes. One-inch steel wire cable costs 19c a foot, weighs about 1½ pounds per foot and has a breaking strain of 33 tons. Its proper load is 6 tons only. Silviculturally this method of steam logging is objectionable.

§ IX. WATER TRANSPORTATION.

Logs or lumber are driven loosely or floated in rafts.

A. Loose driving is a method used in eastern America for short logs, pulp wood and firewood.

Specific gravity of material driven must be reduced below 1.00. Heavy species might be deadened a year before driving, like teak in India, to attain this end, provided that attacks from fungi or insects, on the deadened trees, are not to be feared.

Under favorable conditions, where the creeks are narrow and well watered, no special arrangements for driving are required.

I. Splash dams. The proper site for a splash dam is the rocky narrows of a water course below a broad bottom of little fall, or else at the outlet of a natural lake.

Large splash dams must be placed on rock foundations. The expense of building increases at a cubic ratio with the height of the dam.

Splash dams built in tributaries are preferable to dams in the main creek, provided that they can be filled quickly enough.

A system of dams of first, second and third importance is frequently formed.

The distance of effectiveness of a dam depends on the size of the water reservoir, the width of the water course below the dam, and the rapidity of its fall. On "Big Creek" in Pisgah Forest the distance of effectiveness was four miles.

Splash dams meant to be permanent must be built of stone and are exceedingly expensive.

The usual splash dam consists of timber cribs filled with rock and joined by logs laid crosswise. The front of the dam must be slanting and is covered with a double layer of boards. The gateway of the dam must allow of rapid drawing (or opening) of the basin. The gates are either constructed barn door fashion, held in place by a strong key and lever, or consist of (vertical) piling, the individual piles to be lifted by a crowbar or drum. Half-moon-shaped gates are used in the Lake States and in the Adirondacks.

The smaller the water supply and the greater the pressure the tighter must be the gate.

The expense of a splash dam of the first order is from $1,000 to $2,000. A timber splash dam lasts from six to ten years.

Frequently additional small gates are made to give a "fore-water," meant to loosen the logs in the creek below the dam. The actual splash rather presses the logs down the creek, instead of floating the logs.

II. Dams in the creek bed itself are sometimes required to raise the water in a shallow section.

III. Before driving begins, the creek bed must be cleaned out by removing old log jams, leaning trees and huge boulders. Sharp bends of the creek must be cut through, so as to straighten the creek bed.

IV. Fixtures along the bank of the creek are required to prevent logs from getting smashed when striking a bluff; from being thrown on the bank in a curve of the creek; from destroying the banks, and further to prevent the spread of water and loss of force, where a splash is expected to overrun adjoining flats.

Such bank fixtures consist of:

Pole cribs filled with rock, the poles lying solid, pole to pole, toward the creek, or of inclines of poles laid horizontally, supported by strong uprights from behind, or of alternating layers of fascines and stone, joined together by strong piling driven into the ground; or, finally, of brush laid on the sloping bank and irregularly covered with rock.

V. The bottom of the creek is sometimes paved with stone or poles laid lengthwise, where the bottom consists of clay. This is especially necessary in artificial channels or canals dug through sharp curves of the creek, or dug close to the connecting booms.

VI. Booms.

(a) European booms are rake booms, the teeth of the rake formed by strong palings.

The tops of the teeth are connected by strong timber bars, which are held in place by stone cribs.

These booms are stretched diagonally across the river. The logs or wood are merely diverted by the boom and forced into an artificial side canal ending in a reservoir near the mill or depot.

A gridiron or sieve, filtering the river at a waterfall and retaining the wood on the gridiron, has been used in the Tyrol by the Bavarian Government for many decades.

(b) The American boom consists of two sections, an upper shear boom spanning diagonally across the stream and a lower storage boom stretching for miles along the river bank, where the water is quiet and the current slow. Both booms are floating booms consisting of one or two strings of prime logs, the logs joined by anchor chain. The booms are kept in place either by wire cables ¾-inch to an inch in diameter or by stone filled cribs. It is advisable to have the storage boom consist of independent sections so that the breakage of the boom empties one section only.

Frequently several mill concerns form boom companies.

The logs are lifted out of the booms by "jack works" or "log hoists."

VII. Driving and splashing must be considered a backwoods method, applicable to very cheap stumpage. It is not practiced on the Pacific coast, where we have very cheap stumpage, owing to the size of the logs and poor water facilities. Where there are plenty of natural lakes, in a coniferous country as in the Adirondacks, Michigan and Minnesota, the method continues to be practiced.

Splashing is the more advisable:

(a) The smaller the specific gravity of timber.
(b) The shorter the logs.
(c) The lower the stumpage price.
(d) The more reliable the rainy season and the gauge of the river.
(e) The better the natural conditions are at the dam sites, in creek bed and at boom site.
(f) The poorer the natural conditions are for railroad building and wagon road building.
(g) The less land owned by other parties is traversed by splashed logs.

(h) The more saw timber improves while being bathed in running water.

(i) The longer the distance.

(j) The more inclined the log owner is toward taking risks and the less affected he is by reduced fertility along the river bank.

Remarks: In the pine woods of the South in olden times ditches were dug about three feet wide, connecting stumpage with swamps and rivers.

The outlay per 1,000 board feet in splashing and driving is from 50c to $1 (for manual labor only).

River driving of cord wood at Biltmore from the upper end of the estate to Asheville, inclusive of piling at the boom, costs 50c per cord.

B. Rafting.

Loose logs are tied into rafts at a place where the flow of the creeks and rivers begins to be more gentle.

Only rarely are rafts used in connection with splash dams on very rapid streams. (Black Forest.)

According to the size and species of logs, rafts are formed either with the logs lying with the stream (longleaf pine rafts etc.), or with the logs lying square to the stream. In this latter case the length of the logs should not exceed eighteen feet. Square rafts consist usually of hardwood logs.

I. Logs with the stream.

(a) The logs are joined into raft sections, each section one log long; the narrow end of the log points down stream; joining usually by rope, cable or chain; ring dogs or eye dogs are used, or wooden pins in connection with auger holes.

(b) At the tail section the rear ends of the logs are allowed to spread fan shaped.

(c) The raft is directed by long rudders (sweeps), by brakes (poles which are pressed against the bottom of the river) and pike poles.

(d) The width of the raft and the tightness of binding depend on rapidity of the stream, span of bridges to be passed, sharpness of bends of river and width of river bed.

Remarks: Ring dogs for rafting weigh about 1½ pounds, are four inches long and have a 2½-inch ring, through which rope is run. Price 10c apiece.

Eye dogs are made of ½-inch round iron, are six inches long and cost 6c per pound.

II. Logs square to stream.

(a) The ends are joined by cross poles, sometimes imbedded in the logs and held in place by pins driven into auger holes, or by chain rafting dogs, consisting of two small wedges joined by two rings and five links of chain. Weight 2½ pounds. Price 12c.

(b) The logs must have about equal length. Species not floatable otherwise are tied up with floaters of pine, yellow poplar, cottonwood and linden.

In the Mississippi two oak logs are floated by three cottonwood logs.

(c) Such rafts are naturally stiff and cannot be used on rapid streams. The narrow and wide ends of the logs should alternate so as to keep the sections straight.

C. Flumes.

Flumes resemble chutes made of boards. They must be water tight. They are largely used on the Pacific coast.

I. A V-shaped cross section has proven best. Side boards are equally long, about 16 feet, in double layers. Angle of the V = 110°. Top width is 3 feet to 4 feet.

II. An even constant grade of from 1% to 3% is necessary, also slight curves and large water supply, which is often obtained from artificial reservoirs. High trestle bridges are sometimes required.

III. The main flume has a number of tributaries. A crew is stationed along the flume; special attention is given to the inlets of tributaries. Patrol trails along the flume.

IV. The fluming of logs is said to be unsuccessful. In the West, anyhow, the size and weight of the logs would prevent fluming. Nowadays either planks or heavy dimension stuff, to be resawn at the outlet of the flume, are sent down. Only coniferous lumber is flumed.

The lumber in the flume forms one continuous chain; this arrangement prevents the lumber from sticking and catching at the side walls of the flume.

V. Famous flumes are those at Chico—Sierra Nevada range (40 miles of flume), the flume of the Bridal Veil Lumber Company and the Great Madeira flume, all in California. The last is 54 miles long and has a daily carrying capacity of 400,000 feet of lumber. It cost only $5,000 per mile.

The scarcity of water in California is the greatest obstacle to the continuous use of flumes.

D. Water transportation over lakes and sea is effected in the following way:

I. In the "fiords" of the Pacific coast, logs standing upright are chained together so as to form a stockade in which the other logs are similarly placed, filling it tightly. Such stockades hold about half a million board feet of lumber at a time and form a seaproof raft, pulled to the mill by tugboats.

II. Logs chained together in the form of a cigar-shaped raft after various patterns have proven a failure. These rafts were taken from the Oregon and Washington coast to San Francisco, being launched like a steamboat and towed by tugboats. To judge from newspaper reports cigar-shaped rafts of boards have proven a success.

The steamship companies consider cigar-shaped rafts a great danger to navigation.

III. In carrying logs across the lakes in the Adirondacks and Lake States, light ring booms are used. The logs are placed in such booms at "the landing" and are rafted (driven) to the outlet of the lake either by wind, current or tugboat.

§ X. TRANSPORTATION ON LAND WITH VEHICLES.

A. Sleighs and sleds.

I. Hand sleighs, home made, very light, are frequently used abroad at grades of 10% and more. Man sits in front of load and directs with legs and side brake. On steep slopes such sleighs are used in summer as well. Fifty cubic feet is an average load for one man. The workman carries his sleigh back uphill on his shoulders for the next load.

Sleighing roads for summer sleighing frequently have cross ties at short intervals to be kept greased at slight grades.

II. The American sled has nothing in common with the European sled. A team of horses is always used for motive power.

The sleigh, or sled, consists of two sets:

The front set has a tongue of rock elm or oak and a front roller in which the tongue is set. Runners are 7 feet to 9 feet long, 3 inches to 4 inches wide, shod with ½-inch steel shoes or cast iron shoes either below only or both above and below; they are either slightly convex or flat. The front of the runner should be of a natural curve or crook, not hewn. Material is white oak. The cross beams, either ironed or plain, rest in saddles or nose plates with knees.

The "back roll" of the hind set is coupled to the front set by chains attached to the center of the front cross beam. There is no tongue to the hind set.

III. Log binders are used on loading chains to take about half a foot of slack out of the chain, unless the same end is secured by poles and the twisting of the binding chain.

IV. The usual load of a sleigh is five tons, while a wagon carries only two tons on an average.

The actual load depends on distance, grade and condition of road. In the Adirondacks about 2,000 board feet form a load; in Ontario 1,500 feet of white pine or spruce.

V. Sledding roads are constructed in the Adirondacks at an expense of $25 to $150 per mile. The sledding distance is said not to exceed three miles, usually. The teaming expense is about 10c per 1,000 board feet per mile.

The relative distance of snaking and sledding depends on configuration and density of stand. Sledding roads are preferably built on swampy soil. Heavy grades require a heavy outlay for sanding; insufficient grades a heavy outlay for icing. Carelessness in surveying sleigh roads is extremely expensive in short, mild, snowless winters. The modern lumberman surveys his roads with instrument in hand, completing them before snowfall.

To begin with, an empty or lightly loaded sleigh is run over the road to mark and set the track.

B. Transportation on two-wheelers.

I. High wheelers, wheels 7 feet to 10 feet high, are used in the pineries of the South, in California, and to a certain extent in the Lake States for hauling coniferous logs of 1½ feet average diameter and of extra long length.

Logs are loaded underneath the axle, either by using the tongue as a lever or with the help of a second axle having the form of a winch (Southern method).

Logging distance in the South not to exceed half a mile, average one-quarter of a mile. Expense $1 per 1,000 board feet.

The best makes are:

Bodley Wagon Co., Staunton, Va.; Snyder Wagon Co., Shreveport, La.

Prices from $100 to $150.

II. Low wheelers, usually called "Bummers," the wheels consisting of a solid tree section held by iron rims 1½ feet in diameter. The top of the axle is even with the top of the wheels. The tongue is only six feet long and merely used as a lever in loading. The bummer is pulled by chain attached to point of tongue and is loaded by placing axle parallel to log close to center of log, with the tongue standing perpendicular, the log being fastened to the axle by short chains and dogs.

High and low wheelers are used on undulating ground for downhill pull on soil free from rock, swampy places, debris and brush.

C. Log wagons. Log wagons are entirely used for transportation in the old country, where the forests are traversed by a network of well graded stone roads. Wagons are always handmade, of light weight and carry up to 17 tons of logs.

In carrying long boles, the front and hind trucks are separated. Steep curves can be made if the rear ends of the logs are fastened underneath the axle of the hind truck.

The American wagon has a track width, from center to center of tire, of 4 feet 6 inches or 5 feet.

Wheels are usually made entirely of white oak. The wood is well seasoned. The tire is 3 inches, 5 inches and over. Front and hind wheels usually equally high—2 feet to 3½ feet. Eight wheelers are now widely advertised.

Skeins are preferably made of welded steel instead of cast, 3 inches to 5 inches in diameter.

Steel axles have not proven a success, owing to difficulty of repairs in the backwoods. Bolsters should reach to or over the top of the wheels.

The reach should allow of changing distance between front and rear set.

Main requirements are:

I. Strength.
II. Possibility of repairs in the woods.
III. Low point of gravitation.
IV. Ease of loading.
V. Ease in turning.
VI. Light weight of wagon itself.

Prices for log wagons range from $80 to $200 according to carrying capacity. Weight from 800 to 1,800 pounds. Carrying capacity 1½ to 5 tons.

D. Traction engines. Traction engines are largely used abroad and have proven very successful recently in the South African war. In freighting lumber from mill to city or depot they are used in the United States on a small scale, since stone roads seem to be a prerequisite; loose sand, deep mud or swamp are impracticable for traction engines. In Pennsylvania four-wheelers costing $1,500 for a 16-horsepower compound engine and able to climb 12% grades and to turn 30 feet curves have proven a failure, since the use of traction engines plows the roads during rain.

In the California mountains, where drouth prevails during six months of the year, the three-wheelers manufactured by the Best Company, of San Leandro, Cal., have been largely and successfully introduced. Very high wheels and broad tread cause little injury to the route traveled. The boiler is a combination of upright and horizontal, concentrating weight on the driving wheels and preventing water and fuel from dropping back from the pipes on steep grades. Engines are said to be able to climb 30% grades and to climb over logs, brush, stone etc. Front wheel is for steering only, with front drum for skidding logs by wire cable.

E. Pole roads. A statistic of 1886 finds in the United States over 2,000 miles of pole roads, using over 400 locomotives and over 5,000 trucks.

I. The rails are made of straight, preferably coniferous poles, sufficiently trimmed to fit the double flange of the truck wheels. On suitable soil no ties are required, the rail being gradually pressed into the ground.

Sawn rails, preferably consisting of several layers of boards, must be used in curves of the pole road and are still largely used near mills on steep and short grades.

II. Trucks. The wheels should not turn with the axle. An oval concave rim said to be inferior to a flat rim with heavy flanges.

Each wheel has about 2 inches room for side play. The reach should turn like a swivel in hind and front set, allowing all wheels to stay on the track.

III. All lumbermen now agree that pole roads are impracticable for locomotives. On sawn rails locomotives are still used, however, when prices of steel are high, grade steep, distance short and use intended for a short while only. Sawn wooden rails do not allow of heavy loads and, consequently, seem unadvisable just for logging by steam engines.

F. Forest railroads.

I. Portable forest railroads.

In American lumbering portable railroads are little used. The sections of which portable railroads consist are necessarily light and, consequently, unfit for the heavy traffic of American lumbering. In Europe the sections are usually 6½ feet long, have 2½ feet gauge and weigh 80 pounds. Steel ties are preferable at the ends so as to have the joints supported by ties. The sections are joined by a hook arrangement without being bolted together.

Usually the sections are merely laid on wood roads. Motive power is supplied by gravity, men or horses. Wheel flanges usually on both sides of the rail. Rail sections of trapeze form are sometimes used in building curves. Bridge switches are preferable to split switches.

In the wood yard at Biltmore sections of wooden rails were used, the ties being replaced by iron rods. The top of the rail was shod with a strip of ¼-inch iron, the ends joined by hook and pin, and by hole and pin.

Steel sectional tracks of 2½-inch gauge are manufactured by the C. W. Hunt Co., New York. The trucks used have the wheel flange outside. Curves and switches are ready made. Straight sections are 6 feet to 20 feet long.

II. Stationary track.

(a) Grade. A proper survey is very essential. For steep grades (over 7%) a soft rail is required. Grades of 11% are feasible on straight track for locomotives having eight drivers.

High percentage for very short distance is, however, permissible.

Logging roads in the South have grades running up to 15% for uphill traffic, obtaining the necessary impetus by a corresponding downhill grade. The expense of maintaining the track and the frequency of accidents render steep grades highly expensive.

The standard railroads have never over 4% grade.

(b) Curves. The minimum radius of curves depends on gauge of track; distance between axles of front and hind trucks; length of timber to be carried and grade in the curve. Curvature is measured by the subtended angle, the (secant) chord of which is 100 feet. Standard railroads do not allow of an angle exceeding 10%.

In curves, to relieve the increased friction, and, further, to prevent the trucks from jumping the track, owing to centrifugal force, three remedies are required:

1. Lessened speed and reduced grade.

   In practice for standard gauge of 56½ inches, for each degree of curvature the grade is released by 0.02%; for narrow gauge by 0.03%.

2. The outer rail is elevated for standard track by ½-inch for every degree of curvature; for 36-inch gauge (usual narrow gauge) by 1-3 inch for each degree of curvature.

3. The track is widened in curves by 1-16 inch for every 2½ degrees of curvature.

(c) Rails. The form is usually the T rail. Grooved rails, flat rails, rails inclined toward center of track etc. are freaks merely. In logging railroads the rails are often fastened lengthwise on sawn or hewn stringers, which arrangement allows of light rail. The gauge is measured inside the tops of the rails if the flange is inside, and outside the rails if the flange is outside. If the wheel has a double flange, measure from center to center of rails.

In lumbering operations, the standard gauge (56½ inches) is generally preferred, since heavier loads can be taken and since the rolling stock can be disposed of more readily at the end of operations. Of the narrow gauges 36 inches is best, since the odd gauges prevent ready exchange of addition to and sale of rolling material.

In mountainous sections narrow gauge is preferred. Here the expense of wide gauge track is too high, since it requires flatter curves, smaller grades and largely increased outlay for roadbed.

In standard lumbering operations a heavy (56 pounds) rail is now preferred, the up-keep of track being cheaper, the bed for the track being less expensive and fewer ties being required for the heavy rail. Light rails are so twisted, after short use, that they cannot be sold at second hand. For 36-inch gauge a rail weighing 16 pounds to 20 pounds is best.

Rule for number of tons of rail required per mile:

1. Tons of 2,000 pounds.

   Multiply the weight of the rail by 7/4 and you obtain the number of tons required per mile. For example, 20-pound rail x 7/4 = 35 tons.

2. Tons of 2,240 pounds (after which rails are usually sold).

   Multiply weight of rail by 11/7 instead of by 7/4.

   The price per ton of rail (steel) varies from $25 to $35.

   The interdependence between locomotive's weight and minimum weight of rail permissible is given by the following equation:

$$\frac{w}{n} \times 8 = r$$

   wherein *w* stands for weight of locomotive in tons; *n* stands for number of drivers; r stands for minimum weight of rail in pounds.

Estimates of cost of track, exclusive of rolling stock and bridge arrangements, vary from $1,300 to $4,300 per mile for easy grading. One-half of the expense in this case is for rails, spikes and splice joints (fish plates).

The grading and laying of track costs from $300 to $1,000 per mile for easy grading; and cross ties cost about as much.

Estimate of cost per mile for

1. Sixteen-pound steel rail, requiring

25 tons of rail @ $32 per ton.	$ 800.00
1,780 pounds of 3½x⅜ in. spikes at 2c per pound	35.60
357 splice joints at 20c	71.40
2,640 cross ties at 15c	396.00
Grading and track laying	500.00
Total	$1,803.00

2. 40-pound steel rail, requiring 63

tons of rail at $30 per ton	$1,890.00
4,690 pounds of 4x½ in. spikes at 2c a pound	93.80
357 splice joints at 40c each	142.80
2,640 cross ties at 25c each	660.00
Grading and laying track	1,000.00
Total	$3,786.60

(d) Cars.

Cars consisting of two trucks, of two axles each, form the rule.

The trucks should be very low and should have short distance between axles where curves are heavy. For narrow gauge tracks, special trucks are constructed costing from $50 to $80. While steel trucks are more satisfactory in the old country, in America trucks with wooden framing and wooden bolsters are usually preferred, owing to greater ease of repair far from factory.

The bearings are frequently outside as well as inside the wheels, so as to have the frame supported at eight instead of at four points of the two axles. The bolsters, swiveled on the frame, are very frequently much longer (wider) than the axles.

The weight and capacity of logging cars should be as follows:

	Weight in lbs.	Capacity in board feet.
4 wheel cars	3,000 lbs.	1,000 b. ft.
4 wheel cars	4,000 lbs.	1,500 b. ft.
4 wheel cars	5,000 lbs.	2,000 b. ft.
4 wheel cars	6,000 lbs.	2,500 b. ft.
8 wheel cars	6,900 lbs.	2,000 b. ft.
8 wheel cars	8,400 lbs.	3,000 b. ft.
8 wheel cars	9,600 lbs.	4,000 b. ft.
8 wheel cars	11,000 lbs.	5,000 b. ft.

(e) Locomotives.

Logging locomotives are manufactured by the
Baldwin Locomotive Works, Philadelphia;
H. K. Porter, Pittsburg, Pa.;
Climax Mfg. Co., Corry, Pa.;
Stearns Locomotive Co., Erie, Pa. (for Heissler geared locomotives).

The price is practically independent of the gauge, being influenced more by horsepower.

Four driving wheels are usually sufficient. On steep grades, six wheels and, on very steep grades, eight wheels are used.

The resistance to be overcome by the tractive force is:

1. Gravity, which increases in exact proportion to steepness of grade expressed in per cent. Thus it is always 20 pounds per ton for each per cent.
2. Friction of the journals and of the wheel flanges against the rails, which depends, aside from curvatures, on quality of the track and of rolling stock. It is at least 5 pounds per ton; it amounts to 6½ pounds for first class equipment; to 20 pounds to 40 pounds for bad equipment, and in extreme cases it rises to 100 pounds.

Tractive force is understood to be one-fifth of the weight, in pounds, on the driving wheels, expressed in tons.

For instance:

Weight on driving wheels 25,000 pounds, divided by 5=5,000 pounds; and 5,000 tons is therefore the tractive force of the engine.

The hauling capacity of an engine is: tractive force divided by the sum of the frictional and gravity resistance, both expressed in pounds, deducting the weight of the locomotive from the quotient. For example:

Weight of locomotive on 4 driving wheels = 20,000 pounds. Tractive force is 4,000 tons.

First case—Frictional resistance 8 pounds per ton, grade level. Then the hauling capacity equals 4,000 tons over 8 (friction) plus 0 (gravity) minus 10 = 490 tons.

$$\frac{4000}{8+0} \text{ minus } 10 = 490 \text{ tons.}$$

Second case—Frictional resistance same as above, grade 1%.

$$\frac{4000}{8+20} \text{ minus } 10 = 133 \text{ tons.}$$

Third case—Frictional resistance 8 pounds, grade 2%.

$$\frac{4000}{8+40} \text{ minus } 10 = 73 \text{ tons.}$$

The cost of hauling logs on a standard railroad, per carload of 40,000 pounds, amounts to \$5 for distances of one to fifty miles, and to \$6 for distances of fifty to one hundred miles.

Porter's catalogue gives the cost of hauling as ranging from 30c to 60c per 1,000 b. ft. for a logging distance of from five to ten miles. At Chicora, Ala., two standard trains provide daily, together, 100,000 b. ft., coming from a distance of about eight miles.

Small (narrow gauge) locomotives haul from 60,000 to 120,000 b. ft. per week over distances of from five to ten miles.

Where grades are not excessive, a locomotive should cover daily 60 to 80 miles, the hauling distance varying from 2 to 10 miles.

G. Mono rail.

The mono rail portable railway is a French invention (Caillet) and has been tried to a limited extent in India.

It consists of one rail only, resting on steel sole plates at intervals of a few feet, and is laid down direct on the surface of the ground. Rails are joined together by scabbard fish plates. The trucks have two low wheels, grooved at the rim, the carriage hanging between the wheels a few inches above the rail. Cars are balanced by a telescopic rod and kept in balance, like a bicycle, by the motive power itself, which consists of an animal hitched in a frame alongside of the carriage.

The mono rail system might be applicable in the transportation of bark, cordwood and minerals.

H. Cable way logging.

The logs are suspended from a cable and are not dragged on the ground.

I. On steep slopes, the grade being 35% to 50%, the logs slide down by gravity, being suspended from two trolley blocks held apart by a strong rod or pole, about 15 feet long. At the upper end of the cable, curved iron rails lead, like a bridge switch, onto the cable. The cable is kept tight by heavy drums, over which the cable runs at the ends. It is said to wear out in about eight years.

The speed of the block carriage is regulated by manila rope, wire or light wire cable, and the empty block carriage is carried backward by the same rope without any motive power other than that of a loaded block carriage going down hill. Proper switches allow the empty block carriage to pass the loaded one at a half-way point. The price of 1-inch wire cable is about 19c per foot.

In Switzerland lines two miles long are found, without any supports. In the Hartz Mountains supports are given every 700 feet and the expense is $800 per mile for entire equipment.

In Oregon and western North Carolina short cable conduits of this character are in successful use, and in India (in the Himalayas) the most extensive plants of this character are said to exist.

II. In swamps of the Atlantic coast, where railroading is difficult, the system of the Trenton Iron Co. and of the Lidgerwood Manufacturing Co. have been tried which move the block carriage holding the logs in suspense over a cable either by steam power or by electricity.

(a) In case of steam power, the engine is placed either on a scow swimming in the swamp, in the river, in the logging canal cut by powerful dredges, or on a railroad car, the logging outfit costing about $7,500 per mile (including lateral rig), consisting of:

One-inch carrying cable and double traction rope;

Double block carriage with differential hoist and log grip;

Brackets, supporting the cable;

Steam engine with hoisting drum;

Lateral hauling-in rig, by which logs are dragged to the main carrying line over distances running up to 1,000 feet.

(b) In case of electric power, the outfit, costing $6,200 per mile, consists of:

One-inch carrying cable and ½-inch single current rope, which is swung thrice over a grooved sheave;

Generating machines and 20-horsepower steam engine;

Carriage, including the log support and the motor with sheave, which has a speed of six miles an hour.

I. Loading arrangements are required, wherever vehicles are used, except for bummers.

I. Loading on wagons.

(a) Sliding logs from a higher bank onto vehicles. Only one layer can thus be loaded conveniently.

(b) Rolling logs up an incline, either with peavies or rope, the top of the incline resting on the tops of the wheels.

(c) A (drum) winch in front of wagon, incline behind wagon, pulling logs up by rope.

(d) Tackle block attached to a tree, the wagon standing between the tree and log; the end of rope attached to outside wheel and the free end pulled by animals.

(e) The skidway scheme. Trained horses running on prepared track opposite the skidway. Two poles leading from skidway to wagon; rope running from outer wheel of wagon under and around the log and back over the wagon to the horses.

(f) A jack, consisting of a gear wheel and a toothed iron rod.

(g) German lever arrangement.

II. Loading on railroad cars.

Additional methods.

(a) A huge tripod and Weston's differential hoist.

(b) A drum and wire cable rig, the loading cable running over a tackle block suspended over track.

(c) Cranes or derricks as used on the harbor docks, a special make of which is known as the

"Decker log loader." There is some mechanical difficulty in constructing loaders of a sufficient angle of leverage.

§ XI. CHOICE BETWEEN THE VARIOUS SYSTEMS OF TRANSPORTATION.

Conditions governing the selection of means of transportation are:

A. Topography. Steep grades make it advisable to send products down by their own weight, so that animals and vehicles need not reascend the grade.

B. Periodicity of rain and snow fall (West Virginia for spring rains, Lake States for snow fall, California for spring drouth) invite the use of means relying on water supply, on layers of snow, on dry soil.

C. Rocky soil entails blasting expenses and thus bars railroading and road building, Wet or swampy soil requires an artificial surface on which means of transportation are placed.

D. Existence of drivable creeks and rivers, their grade, rockiness, curves, steadiness of flow, the spans and number of bridges crossing them, the danger or help expected from freshets are factors bearing on the advisability of water courses used as means of transportation. Electric power derivable from water falls might be used as motive power in days to come.

E. Availability of building material in the forest, especially the price of rails and ties and quality of stone etc.

F. Total amount of stumpage, and stumpage per acre to be carried away from a given locality annually, periodically or once only.

G. Maximum weight and size, also average weight and size of pieces to be handled.

H. Price and effect of day labor and prospects of changing prices under the influence of labor laws and socialistic legislation.

I. Relative price of team labor and of manual labor. The ratio between price of hand labor and team labor abroad is 1 to 8. In this country it is 1 to 2½; in Lake States even less, viz., 1 to 2.

J. Condition of existing public means of transportation; roads, railroads and navigable rivers.

K. Laws relative to rights of way and relative to damage inflicted on outsiders in the course of transportation, i. e., by splashing logs; raising water level of lakes and thus destroying trees etc.

L. Mileage of the various links forming the chain of transportation and speculation as to the building of additional public links of transportation.

M. Silvicultural considerations, or choice between conservative and destructive lumbering.

Donkey engines are the destroyers of any second growth left on the ground and should be used only in clear cutting.

High two wheel logging carts are used abroad to save young growth.

N. Possibility and amount of damage to logs and loss of logs in course of transportation. Loss of bark. Loss of sap-wood. Deterioration by fungi and insects. Theft. Loss of interest on value of logs.

O. Regularity and reliability of means of transportation.

P. Possibility of using the means of transportation for purposes other than carrying forest products (access to mines and farms; passenger traffic; supplies for lumber camps; use of snaking roads as fire lanes, patrol trails, sport trails).

Q. The general political and economic condition of the country (settled or unsettled); the possibility of financial surprises.

Part III. Manufacture of Wood Products.

CHAPTER IV. FOUNDATIONS OF MANUFACTURE.

§ XII. THE AMERICAN FORESTER AS A LUMBERMAN.

In the old country, a large portion of the products grown in the forest go to the holders of prescriptive rights (easements). The balance is sold either under private contract or at public auction or under sealed bids.

In France, standing stumpage is sold, while in Germany the trees are dissected, at the owner's expense, into assortments required by the local manufacturing trades.

Usually, in the old country, the raw products of the forest are not refined by the forest owner. The forest industries are in the hands of parties who do not own or control an acre of woodland.

In Canada, timber leases or timber limits are sold at public auction. The purchaser pays, aside from the auction price, an annual rental (so called ground rent) and, further, for every 1,000 feet b. m. cut, a specified royalty. Neither ground rent nor royalty is object of the auction sale.

On the forest reserves of the United States auction sales are meant to form the main method of disposal of forest products, exceptions being made only in the interest of local residents.

The private owner of woodlands in the United States, and his forester, is and will be compelled to be a wood manufacturer for many a year to come.

The lumberman need not be a forester; but the forester must be a full fledged and experienced lumberman. Woe to conservative forestry in the United States if the forester, satisfied to give theoretical advice, fails to devote to lumbering and manufacture the larger part of his energy!

§ XIII. MOTIVE POWER.

Motive power is supplied by:

A. Actual animal power said to be used in Texas for running portable saw mills.

B. Wind-mills, which furnish an insufficient and unreliable power.

C. Water-mills. The horse power of falling water is:

$$\frac{v \times h \times 62.5}{33000},$$

wherein stands: v for volume of discharge in cubic feet per minute;
and h for height of fall in feet; and
wherein 62.5 represents the weight of a cubic foot of water and 33,000 equals one horsepower per minute.

For example, if cross section of a race is = 2 sq. ft., water velocity = 660 ft. per minute, height of water fall 30 ft., then the power is:

$$\frac{2 \times 30 \times 600 \times 62.5}{33000} = 75 \text{ H. P.}$$

Water wheels are either vertical, i. e., overshot, breast or undershot wheels, or horizontal wheels, i. e., turbines.

I. Overshot wheel. Effective power is 60% to 70% of possible power. The proper velocity at the circumference is 5 feet per second and at best if it is equal to 0.55 of velocity of water.

In falls of 20 feet to 40 feet and over, overshot wheels are more effective than turbines.

The buckets, framed by the shrouding, should be curved or elbowed and not radial. They should have a capacity three times as large as the volume of water actually carried, a depth of 10 inches to 12 inches and a distance apart, from center to center, of 12 inches.

Ventilated buckets, having holes in the bottom and allowing air to escape, are said to have a better effect.

It is difficult to transform the slow speed of an overshot into the rapid speed required for a circular saw. Transformation is either by countershaft or by cog wheel.

II. The breast wheel has an effective power of from 45% to 65%, is best applied to falls of from 5 feet to 15 feet and to a discharge of from 5 to 80 cubic feet per second. While in the overshot the water works by weight only, it works in the breast wheel largely by impact.

The velocity of wheel should be such as to fill the buckets to 0.5 or 0.6 of their volume. The buckets here are usually called blades and must be ventilated.

The wheel runs in a curb or mantle, formed by the inclined and cased end of the sluiceway.

The distance of the blades, from center to center, should equal the depth of the shrouding, both being from 10 inches to 15 inches. The clearance between the curb and the shrouding must be at least half an inch.

"High breast" wheels are semiovershot and "low breast" wheels are semiundershot wheels.

The "flutter" wheel is a low breast wheel of small diameter and high speed. It is largely used in western North Carolina for saw-mill purposes where water is plentiful and fall about 12 feet.

III. Undershot or current wheels have an efficiency of from 27% to 45% only and are usually kept anchored in rapid streams, so as to be independent of water gauge. No buckets, but long blades instead.

The diameter of the wheel is from 13 feet to 16½ feet; usually 12 blades, the depth of which is 3 feet to 4 feet. The blades should be completely submerged when passing underneath the axle.

IV. Turbines have an efficiency of 60% to 80%. The water does not work by weight, but by impact, pressure, reaction and suction.

The speed is much higher than in vertical wheels and hence is well adapted for circular saw mills.

A turbine, however, is badly affected by variations of water supply and suffers from debris and sand and ice. The effect of the water is greatest when the turbine is entirely under water, the flow of water filling the curved channel completely.

Turbines are:

(a) Outward flow turbines, water fed from near the center.

(b) Downward flow turbines, water fed and pressing from above.

(c) Inward flow turbines, water fed from the perimeter.

(d) Reaction turbines, working after the principle of a lawn sprinkler.

(e) Impulse turbines, principle of flutter wheels.

Modern turbines are worked both by impact and reaction and, if possible, by suction.

A 9-inch turbine, furnishing 14 horsepower, costs $250, plus $100 for setting it in masonry.

The advantages of water mills are: no fuel, no fireman, no engineer, no explosion, less insurance, possibility of using dust and slabs for stable bedding, laths etc.

Disadvantages are: usually small power, small speed and small capacity. Power less controllable, less reliable than steam power and not portable.

Small capacity does not justify a large outlay for good sawmill machinery.

D. Steam mills.

For circular saws, the number of horsepower required is about = 1/3 the diameter of the saw. For example, a 48-inch circular saw requires 16 horsepower. Ten horsepower are said to manufacture 5,000 b. feet daily in circular sawmills, and 30 horsepower will cut 30,000 b. feet daily. Every additional horsepower should increase the capacity by 1,000 b. feet.

In large mills each horsepower ought to manufacture 1,000 b. feet; in small mills only 500 b. feet.

Boilers in common use are designated as:

I. Internally fired boilers, when firebox and waterbox are comprised by one and the same steel shell; so all portable boilers and all locomotive boilers.

(a) Cornish boiler: large flues below and return flue above water through entire length of boiler.

(b) Lancashire boiler: divided flue below and divided flue above water through entire length of boiler, so as to even the draft when firing, and so as to strengthen the broad heating surface.

(c) Galloway boiler: like Cornish but V-shaped tubes beset the boiler proper, thus increasing the heating surface and strengthening the flue.

(d) Locomotive boiler: firebox surrounded by a waterleg on all sides, excepting at the grate below. A bank of small tubes carries gases to an "extension" or "smoke box" in front of smoke stack.

II. Externally fired boilers: masonry firebox underneath boiler which is traversed by a large number of tubes. Gases pass first to combustion chamber at rear end and then through tubes back to front.

To II belongs the water tube boiler, with inclined tubes, a horizontal top vessel and vertical tail tubes, creating a continuous circuit of water.

(a) Pointers about boilers.

1. Twelve square feet of heating surface of boiler furnish one horsepower.

2. Each nominal horsepower requires one cubic foot or 7½ gallons of water per hour.

3. Mud drum at base of boiler to receive impurities deposited by water. Where no mud drum exists, boiler should be blown off weekly through a bottom valve (mud cock).

4. Steam and water capacity must be sufficient to prevent any fluctuation in pressure or water level.

5. A large water surface (horizontal versus upright boilers) prevents steam from bearing water particles along. Usefulness of dome is doubtful as a means to secure the return of watery particles to the boiler.

6. Water should occupy three-quarters of boiler space.

Water space should be divided into sections, an arrangement improving the circulation of water and reducing the severity of any explosion.

7. Modern boilers are tubular boilers, which have the largest heating surface. Diameter of tubes is measured outside, including metal.

8. Combustion chamber should allow of full combustion of fuel and gases. Draft area should be one-eighth of grate area. Return flues pass the gases to the entrance of the combustion chamber.

   Heating surface should be as nearly as possible at right angles to the current of escaping gases.

9. Very best water gauges, safety valves, injectors and steam gauges are prerequisites. All boiler fixtures should be readily accessible.

10. Safety valves must be tried once daily. The water level should be controlled by gauge cocks, glass gauges alone being unreliable.

11. Cold water should not be fed directly into boiler and should never come in direct contact with the boiler metal. Steam injectors will not lift hot water as well as cold water.

12. Steam pressure gauge must stand at zero when pressure is off.

13. In case of low water and danger of explosion, cover fire with wet earth.

14. If fire is fed from mill refuse, steady heat can be retained only with boilers of large water capacity. The larger the boiler the greater the fuel economy.

(b) Pointers about engines.

1. Horsepower of engines is:

   Sectional area of piston in square inches times pressure times velocity in feet over 550.

   Deduct 10% to 20% for friction.

   Pressure on the piston is not much over one-half of pressure in the boiler (60%).

2. Interdependence between size of cylinder and horsepower actually developed is approximately:

Diameter, inches	8	9	10	12	12	12	14	16
Length, inches	15	15	15	15	20	24	24	30
Horsepower	12	15	20	25	30	35	50	85

These figures hold good for single cylinder engines and are much lower than the usual catalogue figures. A new engine develops more power than an old one.

3. The flywheel should weigh 600 pounds for every inch of cylinder diameter.
4. Double cylinders are more effective than single cylinders, especially if not hitched tandem fashion, which arrangement, however, allows of using one piston rod.
5. Center crank engines are preferable for small portable saw-mills, since they allow of exchange of flywheel and main driving pulley.
6. Machines cannot get along any better, without care, than horses. Repair and watch the smallest defects. Have the firmest possible foundations. Saw-mill engines are put to the severest possible tests owing to frequent and rapid change of strain.

§ XIV. TRANSMISSION OF POWER.

A. Belts.

Belts in woodworking establishments are always dry and dusty and are kept at a high and often irregular rate of speed. Dust materially decreases the transmitting power of belts.

The heavier the belt the more powerful; use light belt on small pulleys, however, for high speeds.

I. Pointers about belts.

(a) Belt tighteners are required where a belt itself is not heavy and not long enough to cause sufficient sag.

(b) The sag should always be on top and not on the bottom.

(c) The angle of belt against the horizon should not exceed 45°.

(d) Placing one pulley above another requires tight belt, which causes heating in the bearings and destruction to the belt.

(e) Belts should run off a shaft in opposite directions to relieve one sided friction of shaft in bearings.
(f) The pulley must be wider than the belt.
(g) The larger the pulley the greater the tractive power of the belt.
(h) Be sure that the belt does not rub against any beam or other solid object.
(i) Long belts have greater adhesion than short belts because they have more weight.
(j) Belt dressing, to prevent slipping off of belt, is objectionable, because it gathers dust and dirt, except perhaps linseed oil used on rubber belts.
(k) Belts will slip if:
1. The pulleys do not run in one and the same plane.
2. The shaftings are not parallel.
3. The pulley is not as wide as the belt.
4. The belt ends are improperly joined.
5. The speed is too high for the weight of the belt.

II. Kinds of belts:

(a) Leather belts.

Leather belts are either single or double. They come in rolls of from 200 feet to 300 feet, are run with the grain side in and are preferably joined with studs—not by leather laces requiring holes; belt cement is now largely used, laps being joined to a fine edge.

Leather belts must be very well protected from moisture, grease, lubricating oil etc.

Transmitting power of a single belt is only 70% of that of a double belt.

The price of a 7-inch single belt per running foot is $1. For double belt $2.

(b) Rubber belts.

Rubber belts withstand moisture better than leather belts. They are cut from ⅛ inch to ¼ inch shorter per foot than the circuit on which they run and are run with seam side out.

They are sold as 2, 4, 6 or 8 ply rubber belt, the 4 ply being equivalent to single leather belting and the 6-ply to double leather belting.

The price of 4-ply 7-inch rubber belting is 70c per running foot; of 6-ply, $1.

The ends are joined either by belt cement or by lace leather. The laps are strengthened by a strip of leather on the outside.

Never use metal studs in rubber belts.

B. Pulleys.

Pulleys are made either of iron or of wood.

The adhesion of leather to wood is much greater than to iron, hence greater transmitting power of wooden pulleys.

Split wood pulleys are preferable. The best make is the Dodge split wood pulley, costing for 24-inch diameter and 10-inch face $11.20.

The so called clutch pulleys consist of two wheels wedged one into the other, the inner one loose, the outer one fastened onto the shaft.

Iron pulleys must be absolutely symmetrical.

Pulleys for stationary belts are slightly crowning, while those for shifting belts are straight faced.

Pulleys for heavy work should be placed close to bearings of shaft. The main driving pulley must stand between bearings not over four or five feet apart.

The ratio between the speed of driving and driven pulley is inverse to the ratio of the diameter.

Remarks relative to starting and stopping machinery:

I. Machinery is started by belt tighteners, the belt running over flanged pulleys, by clutch pulley, by tight and loose pulley with shifting belt, by eccentric boxes and by friction pulleys.

II. A rotation is reversed by crossed belts (belt turning 180°) or by paper friction pulleys or by forcing the belt against a driven pulley remaining outside the belt circuit.

III. A rotation is turned at right angles by giving the belt a quarter-twist (90°), or by gear and pinion or by beveled friction.

C. Shafting.

Cold rolled shafting is said to have a torsional strength 30% greater than that of hot rolled shafting.

The usual diameters of shafting in saw mills are from 1½ inch to 3½ inch. The proper speed for shafting is 300 to 400 revolutions and its transmitting power is given as $\frac{D^3 \times R}{80}$ = horsepower.

Herein stands: D for diameter of shafting;
R for revolutions of shafting per minute;
80 for a constant factor.

Couplings by which the sections of shafting are joined should be close to a hanger or a support. They should be easily detachable without driving keys.

Shafting comes in sections usually 12, 14, 16 or 18 feet long.

The section closest to the main driven pulley is often stronger than the other sections.

The bearings should be long, say four times as long as the shafting is thick, and should have self-lubricating devices.

Hangers for 3-inch shafting and of 3-ft. drop cost about $20.

Bearing-boxes are lined with an anti-friction alloy melting easily and offering little friction even under severe pressure. A space of ⅛ inch to ½ inch is left between the cast-iron box and the shafting (journal) to be supported. The box is held in a "babbitting jig" while the melted alloy is poured from a ladle. Babbitt metal (invented by Isaac Babbitt) consists of about 96 parts tin, 4 parts copper and 8 parts antimony.

Rules for shafting are:

I. Be sure that line of shafting is parallel to axis of driver.

II. Place all heavy work on the main shaft and close to the main driver.

III. Oil freely and watch bearings constantly. Oil after stopping work, while bearings are still warm.

IV. Drive only minor machinery from gear wheels.

Price of shafting is about 5c or 6c per lb.

§ XV. TECHNICAL USE MADE OF THE TREES, BY SPECIES.

A. Hardwoods.

Cucumber tree: Ox yokes; pump logs; water troughs; cabinet making; ceiling; flooring; invariably mixed with and substituted for yellow poplar.

Tulip tree or yellow poplar: Panels; flooring; molding; clapboarding; sheathing; shingles; siding on railroad cars; interior finish of Pullman cars; coffins; cheap furniture; bodies of carriages and sleighs; sides and bottoms of farm wagon beds; woodenware; bungs; slack barrels and tobacco hogsheads (staves and heading); backing for pianos and for veneers; boxes, especially biscuit boxes and cigar boxes; scroll saw work; wood carving; wood burning; matches; excelsior; paper pulp.

Linden or basswood: Mirror and picture backs; drawers and backs of furniture; molding; woodenware; panels and bodies of carriages; ceiling; wooden shoes abroad; inner soles of shoes; cooperage heading; slack barrel staves; butter churns; laths; boxes; grape baskets; excelsior; parts of pianos and organs; fine carving; papier mache; paper pulp. The flowers are used for tea; the inner bark for coarse cordage and matting.

Holly or ilex: Mallets; edging and engraving blocks; fine cabinet work; painting on wood; tool handles; mathematical instruments.

Buckeye: Artificial limbs; woodenware; paper pulp; wooden hats; fine wood carving.

Maple (western): Furniture; axe handles; frames of snowshoes.

Maple (eastern): Furniture (curly and birdseye); flooring; sugar barrels; mantels; runners of sleighs; peavy handles; ox yokes; axe handles; sides and bridges of violins; woodenware; wooden shovels; shoe pegs and lasts; gun stocks; saddle trees; teeth of wooden gear wheels; piano keys and hammers; wood split pulleys; framework of machinery; ship building; maple sugar; surveyor's implements; plane stocks; wooden types; faucets; clothespins; charcoal; acetate of lime; wood alcohol.

Sumach: Tanning; dyeing and dressing skins; Japanese lacquer work.

Black locust: Police clubs; fence posts; insulator pins; construction work (bridge); turnery; wheelwright work; tree nails (pins); ship building (ribs); hubs of wheels; house foundation.

Mesquit: Fence posts and rails; used extensively for fuel (destructive to boilers).

Black cherry: Fine furniture; cabinet work; interior finish; tool handles; surveyor's implements.

Crabapple: Pipes, mallets; wooden measure rules; tool handles.

Witch hazel: Pond's extract.

Dogwood: Tool handles; spools; bobbins; shuttles; mauls; wheel hubs; machinery bearings; engraving blocks.

Black gum: Heavy (wagon) hubs; rollers in glass factories; mangles; ox yokes; stock of sledge hammers in steam forges; veneers for berry baskets and butter dishes; slack barrels; in cheap furniture, for backing and drawers; barn flooring.

Tupelo gum: Chemical paper fibre; slack barrel staves (rotary veneer cut); wooden shoes and woodenware; the corky root is used under the name of corkwood for bicycle handles and floaters of fishing nets.

Sweet gum: Known in Europe as satin walnut and used for fine furniture and cabinet work, in America for cheap furniture; cheap building lumber; flooring; plug tobacco and cigar boxes; wagon beds; slack barrels; strawberry boxes; veneer cut dishes; coiled hoops; street paving.

Sourwood: Tool handles; machinery bearings; sled runners.

Rhododendron: Bruyere pipes; tool handles; turnery; toys; rustic furniture.

Persimmon: Bobbins; spools; shuttles; tools; golf club heads; plane stocks; shoe lasts; wood engraving. The black heart is cut into veneers and used for ebony.

White ash: Wagons and carriages (poles, shafts, frames); interior woodwork; inner parts of furniture; mantelpieces; sporting goods (bats etc.), oars and gymnastic bars; lances; agricultural implements; tennis racquets; snowshoes; skis; wooden pulleys; barrel hoops; pork barrel staves; baskets; dairy packings (firkins, tubs etc.); tool handles.

Catalpa: Fence posts; railroad ties; telegraph poles.

Sassafras: Light skiffs; fence posts; rails; cooperage; insect-proof boxes; ox yokes. Roots used to make sarsaparilla.

California laurel: Ship building; cabinet work and interior finish.

Elms: Wheel stock, especially hubs; fence posts; ribs of small boats; top spans in covered railroad cars; railroad ties; tongues for sleighs and sleigh runners; saddle trees; flooring; exported for inner lining of boats; butcher blocks and churns (butter); cheese boxes; imitation oak furniture; sugar and flour barrel staves; patent coiled hoops for slack cooperage; agricultural implements; bicycle rims; basket making; gun stocks; frame timber of piano cases; wheelbarrows; hockey sticks.

Hackberry: Fencing; occasionally for cheap furniture; hames.

Mulberry: Fencing; cooperage; in the South for boat building; axe handles.

Osage orange: Fencing; paving blocks; railroad ties; wheel stock; toothpicks; fine mallets.

Sycamore: Furniture; plug tobacco boxes; butchers' blocks; interior finish; beehives (hollow log sections); butter and lard trays; wooden bowls.

Walnuts: Interior finish; furniture; gun stocks; tool handles; cabinet work; boat building.

Hickories: Axe handles; wagon stock, especially whiffletrees; neck yokes; spokes; tongues; felloes; skeins; buckboards; rustic furniture; barrel hoops; screws; mallets; parts of textile machinery; farm implements; wooden rails (top); baskets; bows of ox yokes; boat building; hickory bark for flavoring sugar (to imitate maple syrup).

Oaks (white and burr): Furniture; wagon and carriage stock, especially spokes, felloes, hubs, tongues, hounds, bolsters, sandboards, reaches, brake bars, axletrees, whiffletrees; railroad ties; freight car building (framework); ship building; house building and interior finish; shingles; agricultural implements; bridge building; mining timber; wine, beer and whisky barrels; parquet flooring; staircases; split wood baskets; hogshead and barrel hoops.

Post oak: Fencing; railroad ties; construction; staves; carriage and wagon work; farm implements.

Basket oak: Baskets; cooperage; wheel stock; fencing; agricultural implements; construction.

Chestnut oak: Bark used for tanning; fencing; bridges; railroad ties; substitute for white oak, but objectionable in tight cooperage.

Live oak: Ship building; furniture.

Red oak: Shingles; furniture; interior finish; tight and slack cooperage.

Texas oak: Same as red oak. Said to check less than red oak.

Black oak: Plow beams; furniture; lumber; bark for tanning and quercitrin.

Tanbark oak: In California bark used for tanning.

Chestnut: Tannin extract; coffins; furniture; interior finish; shingles; fencing; railroad ties; sheathing; jacob staff for compasses; bridge building (trestles); telephone poles; backing of piano veneers; slack barrel hoops and sawn staves.

Beech: Wood alcohol; wood ashes; charcoal; shoe lasts; plane stocks; clothespins; handles; wooden bowls; horse collars (hames); parquet strips; flooring; street paving; railroad ties; sugar barrels. Beech furniture made out of veneers of three or four thicknesses, or bent after steaming.

Hop hornbeam: Posts; levers; tool handles; wagon brake; shoes; wedges.

Hornbeam: Used for same purposes as above, and teeth of gear wheels.

White birch: Toothpicks; shoe pegs and lasts; wood pulp; spools; clothespins; screws; flooring; veneers; furniture; bobbins and spindles; wooden skewers; hand-made barrel hoops.

Gray birch (yellow): Furniture (usually mahogany finish); match boxes; wheel hubs; tool handles; buttons; brush backs; shoe pegs; clothespins; sugar barrels; dry distillation for wood vinegar; wood alcohol; charcoal etc.

River birch: Furniture; woodenware; wooden shoes; ox yokes.

Cherry birch (sweet birch): Imitation cherry furniture; ship building; bark distilled for oil of wintergreen.

Oregon alder: Furniture; cigar boxes; mining props and water conduits; charcoal in gunpowder.

Black willows: Osier culture (imported species); pollarded for fascines; the Missouri species for fence posts after thorough seasoning; bats for baseball; a drug, salicylic acid, made from the bark; charcoal for smokeless powder.

Cottonwoods: Boxes; wood pulp and fibre; slack barrels; woodenware; flooring; excelsior; backing for veneers in organs and pianos; matches; cheap building lumber; cheap furniture; wagon beds; turnery; woodenware; fence boards.

B. Conifers.

Incense cedar: Water flumes; fencing; furniture; interior finish; laths and shingles.

White cedar (northern): Posts; fencing; telegraph poles; railroad ties; tanks and buckets; shingles; street paving; boat lining.

White cedar (Southern): Woodenware; tanks; buckets; barrels; telegraph poles and fence posts; shingles; railroad ties; boats; lampblack.

Red cedar (Pacific): Canoes of Indians; interior finish; fencing; shingles; cooperage; tanks; buckets.

Port Orford cedar (Lawson's cypress): Lumber; inside finishing; flooring; railroad ties; fence posts; matches; ship building. The rosin is a powerful insecticide.

Western juniper: Fences.

Red cedar (of the East): Tanks, posts, buckets; telephone poles; cigar boxes; chests; pencils; interior finish.

Bald cypress: Tanks; shingles; doors; house building; interior finish; sashes; blinds; molasses barrels; railroad ties; posts; car siding; flooring and covering; wharf piles.

Big tree: Lumber; fencing; shingles; construction; water conduits.

Redwood: House building and finishing; shingles; fencing; telegraph poles; vineyard stakes; railroad ties; car lining; tanks; coffins.

Yew. In Oregon for bows and fishing rods.

White pine: House building and finishing; boxes and crates; sash, doors and blinds; shingles; backing of fine veneers; excelsior; matches; laths; woodenware; slack barrels; framing of machinery; furniture; patterns for casting metals; ship masts; baled shavings for filtering gas, bedding for horses, packing for crockery.

Sugar pine: Same uses as white pine; cooperage; shakes (large board shingles).

Lodge-pole pine: Cheap lumber; mining timbers; railroad ties; used where other timber is not available.

Loblolly pine: Common lumber and cheap veneers, usually mixed with "echinata"; shingles; house building purposes altogether; mining timber; boxes; rice and potato barrels; laths.

Shortleaf pine (echinata): Same use as above; boxes for naval stores.

Table mountain pine: In Pennsylvania used for charcoal.

Longleaf and Cuban pine: House building; dimension stuff; shingles; tanks; flooring; interior finish; railroad ties; railroad bridges; car sills and framework of cars; furniture; sash, doors and blinds; framework of machinery; mining timber; ship building; masts; wagon tongues and beds; naval stores.

Scrub pine (Virginiana): In Kentucky, for lumber.

Jeffrey's pine: Coarse lumber; mining timber.

Bull pine (ponderosa): Lumber; railroad ties; mine props; shingles; boxes; slack barrels.

Jack pine (divaricata): Ties and piling; cheap lumber; boxes; laths.

Norway pine: Lumber generally; ship building; construction; flooring; masts; piles of wharves; covering; lining; siding; flooring and sills of railroad cars; railroad ties.

Eastern spruce: Chemical fibre and paper pulp (down to 5"-diameter); matches; excelsior; construction; posts; railroad ties; fresh-water ship building; clapboards; flooring; ceiling; stepladders; sounding boards (from butt logs); oars; spars; wharf piles; telegraph poles; toys; wood type; butter buckets; slack cooperage; wooden thread (for mattings); chewing gum; vanillin. In Europe spruce bark is used for tanning.

Engelmann's spruce: Used in Colorado for common lumber.

Tideland spruce: Lumber; construction; outer finish; woodenware; paper pulp.

Hemlock: Coarse rat-proof lumber; dimension stuff and construction; shingles; railroad ties; fencing; paper pulp; bark for tanning.

Douglas fir: All building lumber; construction; railroad ties; trestle bridges; piles; car sills; ship building; masts; mining timber; bark sometimes used for tanning.

Firs: Paper pulp. In the East for corduroying. In the West for local lumber; packing cases; cooperage; interior finish; mine props.

Tamarack (Eastern): Fence posts; telegraph poles; ship's knees; railroad ties.

Tamarack (Western): Posts; railroad ties; car construction; dimension stuff.

C. Tropical and subtropical timber.

Yucca: Paper pulp and fibre for ropes; pincushions.

Eucalyptus: Street paving; railroad ties; mine props; piles; ship building; wagon making; orchard paling.

Mangrove: Bark very rich in tannin.

Palmetto: Wharf piles; pincushions; brushes.

Lignumvitae: Bowling balls; blocks for pulleys; fine interior finish and furniture; railroad ties in Panama.

Teak: Ship building and flooring; railroad cars; street paving.

West India cedar: Racing boats; cigar boxes.

Olivewood: Turnery; inlaying; furniture; backs of hair brushes; wood carving. The fruit yields the best oil for table use.

Quebracho: Tanning; paving; railroad ties.

Lancewood: Fishing rods.

Mahogany: Furniture; ship building; pianos; fine interior finish.

§ XIV. TECHNICAL QUALITIES OF THE TREES.

A. Botanical structure of the trees.

I. Botanical structure of hardwoods.

The cells forming the woody tissue are:

(a) Ducts (pores, vessels) formed by the resorption of the partition walls in a vertically running string of cells. Such ducts are characteristic of hardwoods.

(b) Sclerenchyma, cells of heavy walls and small lumina, usually forming long fibres.

(c) Parenchyma, cells of thin walls and large lumina, frequently containing grains of starch.

Medulla or pith is found in the central column, in the primary, secondary, tertiary rays and (rarely) in medullary spots (birch). The central pith is:

Heavy in ash, maple, elder, catalpa;

Triangular in birch, alder;

Quinquangular in hornbeam.

Broad leaved species are called "ring porous," if the spring wood of the annual ring contains strikingly large pores, or else "diffuse porous," if the ducts are evenly distributed over the entire ring. Sapwood and heartwood are merely distinguished by a difference of color, caused by incrustations of pigments, lignin, tannin etc., in the walls of rings formed a number of years before. The number of years elapsing before incrustation takes place is small in catalpa, chestnut, locust; and larger in yellow poplar, white oak, walnut where it is about thirty or forty years old. Beech, maple, basswood etc. do not form any heartwood.

GENERIC STRUCTURE OF HARDWOODS.

Medullary Rays.	Ringporous always with heart.	Inner pores more numerous, always with heart.	Diffuse porous. Pores absolutely even With heart.	Without heart.
Scarcely visible.	Castanea	Rhamnus	Juglans	Alnus
	Robinia	Rhus	Pyrus malus	Pyrus communis
	Fraxinus	Syringa	Sorbus	Crataegus
	Hicoria		Salix	Betula
			Liriodendron	Aesculus
				Populus
Visible.	Ulmus	Prunus		Tilia
	Morus			Acer
	Ailanthus			Corylus
				Carpinus
				Ilex
Broad.	Quercus	Sambucus		Platanus
	Vitis			Fagus
	Rosa			

II. Botanical structure of softwoods.

(a) The tissue of softwoods is more homogeneous than that of hardwoods. It is mainly formed by tracheae.

The cell walls formed in early spring are thinner and the lumina formed in early spring are larger than those formed in summer.

(b) Parenchyma is found in the medullary rays and around the rosin ducts.

(c) Ducts of the form found in hardwoods exist only close to the central pith column.

(d) The medullary rays are very fine (microscopic), usually only one cell wide and about a dozen cells high. The lowest string of cells in the ray is usually formed by tracheae (exception—red cedar).

(e) Rosin ducts are not cells merely, but, unlike the ducts of hardwoods, hollow tubes, the walls of which are formed by parenchymatic cells. These ducts are running horizontally as well as vertically in picea, pinus, larix, pseudotsuga.

The tissue of the genera abies, taxus, juniperus, thuja, tsuga, chamaecyparis etc. lacks the ducts.

(f) Heartwood and sapwood of conifers are distinguished merely by a difference in color, due to incrustations of rosin in the inner heartwood rings. Pinus echinata has, usually, about thirty sapwood rings. Spruces, firs and hemlocks have no heartwood. Heartwood is conspicuous in the pines, red and white cedars, lawson cypress, yew, larches and douglas fir.

B. Chemical qualities of wood.

I. The walls of the tissue are formed by cellulose ($C_{12}H_{20}O_{10}$) and by lignin ($C_8H_{12}O_5$).

Cellulose transforms, entirely or partially, in the very year in which the cell is built, by incrustation and reduction into lignin. If a branch or a seedling does not enjoy enough light during summer to allow of thorough lignification, then that branch or seedling is necessarily killed by the winter frost.

II. Wood and bark contain on an average 45 % (weight) of water. Conifers contain less water than broad-leafed species. The percentage varies irregularly with the seasons and with the precipitations.

III. Other substances found in the woody tissue are:

(a) In the sap and medulla—albumen, starch, sugar, oils.
(b) In the cell walls—tannin, rosin and pigments.

IV. The specific gravity of pure wood fibre is 1.56.

C. Outer qualities, or qualities discernible by eye, touch or scent.

I. Texture. The texture is fine or rough according to the ease with which parts composing the tissue can be distinguished.

The texture is:

(a) Very fine—yew, box, holly, persimmon.
(b) Fine—pear tree, hornbeam, black gum.
(c) Pretty rough—spruce, fir, magnolia, cottonwoods.
(d) Rough—cherry, sycamore, maple.
(e) Very rough—oak, elm, locust, beech.

II Color. Color is an advantage in the furniture trade and a disadvantage in the manufacture of paper. The heart of seasoned wood is always darker than the sapwood.

Tropical species are particularly rich in color.

Wood exposed to air changes its color more or less visibly. The heart of yellow poplar changes to a dark brown. Alder changes from white to red. Ash from white to light violet. Mahogany from brown to black. Walnut similarly.

III. Gloss. Gloss is due to evenness, number and size of medullary rays.

Shining species are maple, ash, elm, beech.

Medium shining are oak, alder, hornbeam.

Dull are peach, pear, conifers.

Quarter sawing increases the gloss.

IV. Odor. Odor is important for the use of wood in the package industry. The strong odor of wood is usually lost in the course of seasoning. The following species retain, however, a characteristic odor: Cherry, birch, sassafras, red cedar.

D. Inner qualities, or qualities discernible by mechanical tests.

I. Specific gravity.

(a) Pure wood fibre forms in fresh wood, with broad leafed species of temperate climates, about 35 % of the entire weight, while conifers show an average of about 25 %.

(b) Air dried wood still retains from 10 % to 15 % of water. If the dry kiln reduces the percentage of water below that figure, the hygroscopicity of the wood will speedily cause it to return.

(c) Factors influencing specific gravity of air-dried wood within the same species are:

1. The width of the rings, in ring porous hardwoods and in conifers forming heartwood.
2. The incrustations of rosin, tannin and pigments in the heart.
3. The age of the tree.
4. The decay of the fibre.
5. The section of the tree, since roots are very light, butt logs heavy, bole fairly light and branches fairly heavy.

In the case of the diffuse porous hardwoods and of conifers destitute of heart, no rule can be given relative to specific gravity of inner and outer layers, of wide and narrow rings.

(d) Air dried lumber has, on an average, the following weights:

Species—	Specific gravity.	Weight of 1,000 ft. b.m.
Turkey oak, hickory, service-bush.	over 0.75	over 4,000 lbs.
Ash, white and red oak, locust, beech, hornbeam, hard maple, pear tree	0.70-0.75	about 3,750 lbs.
Elm, soft maple, apple tree, sycamore, birch	0.60-0.70	about 3,400 lbs.
Horse chestnut, chestnut, tulip tree, alder, larch, longleaf pine	0.55-0.60	about 3,000 lbs.
Yellow pine, douglas fir, spruce, fir, willow, cottonwood	0.45-0.55	about 2,600 lbs.
White and sugar pine	under 0.45	about 2,200 lbs.

(e) Rules.

1. Specific gravity times 5,200 equals the weight of 1,000 feet b. m. of sawn lumber. Reason—1,000 superficial feet of water one inch deep weigh 5,200 lbs.

2. Specific gravity times 8,000 times cordwood reducing factor equals the weight of a cord of wood. Reason—128 cubic feet of water weigh 8,000 lbs.; a cord of wood contains from 20 % to 85 % of wood, the balance being air.
3. Specific gravity air dry times 5,200 times 23 equals the weight of 1,000 feet b. m. in the log. Reason—a green log has about 10 % bark, about 27 % of water, to be removed by drying, and loses 33 % for slabs and kerf in band sawing. Hence the weight in 1,000 feet b. m. air dried and band sawed lumber is only 0.9 times 0.73 times 0.67 of the weight of a log scaling 1,000 feet b. m. Doyle. The weight of a green log is 2.3 times the weight of air dried lumber obtainable from it by the band saw. For broad-leafed species and for circular saws the figure is higher than for conifers and band saws.

(f) Heavy planks do not dry as thoroughly as thin boards.

(g) Weight determines freight and customs charges. Also adaptability to packages, floatability in flumes and rafts and possibility of loose driving.

Lumber freight rates from Asheville, N. C., are:

29c per 100 lbs. to New York.
23½c per 100 lbs. to Philadelphia.
12½c per 100 lbs. to Atlanta.
18c per 100 lbs. to Washington.
14c per 100 lbs. to Norfolk.

Lumber freight rate from Portland, Ore., to Chicago is about 50c per 100 lbs.

Steamer rate to Europe from Norfolk is 14c per 100 lbs. of lumber.

The freight rate on logs for 50 miles is at least $5 per carload; for 100 miles at least $6.

II. Hardness.

By hardness is understood the resistance of the fibre to axe and saw worked vertically to the fibre.

Factors of hardness are:

(a) Density; wide rings in oak and narrow rings in pine increase the hardness.

(b) Incrustation; heartwood is harder than sapwood.

(c) Moisture contents; dry wood is, on the whole, harder than green wood. With some broad-leafed species of loose tissue (willows and cottonwoods), however, moist wood is tougher and therefore harder as well.

(d) Frost increases the hardness.

SCHEDULE OF HARDNESS.

Hard.	Medium.	Soft.	Very soft.
Hickory	Ash	Chestnut	White pine
Dogwood	Oak	Tulip tree	Sugar pine
Sugar maple	Elm	Sweet gum	Sequoia
Sycamore	Beech	Douglas fir	Paulownia
Locust	Cherry	Fir	Willow
Hornbeam	Mulberry	Yellow pine	
Persimmon	Birch	Larch	
	Sour gum	Linden	
	Longleaf pine	Horse chestnut	
		Hemlock	
		Cottonwoods	
		Spruce	

III. Cleavability or fissibility.

Cleavability is the resistance of fibre to axe, saw and wedge, worked lengthwise in the direction of the fibre. Radial cleavage is usually by 50% to 100% easier than tangential cleavage (except in black gum).

Factors of cleavability are:

(a) A straight, long, elastic fibre.

(b) Heavy and high medullary rays.

(c) Straightness of growth.

(d) Branchiness.

(e) Moisture (very green and very dry wood splits best).

(f) Frost (reduces the cleavability).

(g) Hardness and softness (extremely hard and extremely soft wood splits badly. This rule holds good only in hardwoods).

SCHEDULE OF CLEAVABILITY.

Hard to split.	Medium to split.	Easy to split.
Black gum	Oak	Chestnut
Elm	Ash	Pines
Sycamore	Larch	Spruce
Dogwood	Cottonwood	Fir
Beech	Linden	Cedar
Holly	Yellow poplar	
Maple	Hickory	
Birch		
Hornbeam		

IV. Pliability.

Under pliability we combine flexibility and elasticity.

(a) Flexibility; wood which is easily bent without breaking is flexile (flexible). Softwoods are naturally less flexile than hardwoods.

Flexibility depends on:

1. Toughness and cohesive force of fibre.
2. Moisture, which increases it very much.
3. Heat, which increases it.
4. Age of tree, inasmuch as young shoots are tougher than old wood.
5. Impregnation, natural as well as artificial,

checks flexibility. (Heartwood less flexible than sapwood.)

6. Root wood more flexible than stem wood.

Remarks: Heat and moisture as a means to increase flexibility are applied in these industries:

Cooperage; for bending staves and hoop poles.

Carriage works; for bending poles, shafts, felloes, top frames, seats etc.

Furniture; bent wood furniture.

Ship building.

Veneer peeling.

Basket work.

Manufacture of musical instruments.

(b) Elasticity and flexibility are not always found in the same piece of wood. On the contrary, qualities which increase flexibility frequently reduce elasticity, and vice versa. Elasticity is the force with which an object resumes its old shape when pressed out of shape and released.

The factors of elasticity are:

1. Long and straight fibre.
2. Narrow rings in conifers.
3. Dryness (moisture reduces elasticity).
4. Frost (which destroys elasticity).
5. Excessive contents of rosin (which increases the elasticity).

SCHEDULE OF ELASTICITY.

Very elastic are:	Less elastic are:
Yew	Cottonwood
Larch	Birch
Fir	Maple
Locust	Elm
Chestnut	Alder
Hickory	Walnut
Osage orange	Yellow pine
Red cedar	Yellow poplar
Lancewood	Beech
Spruce	
White pine	
Ash	
Oak	

V. Strength.

Strength is resistance to:

(a) Tension; to which timber is usually not exposed. (Yoke of oxen pulling the cart by the pole.)

(b) Compression (arches, pillars, scantling).

(c) Torsion (shafts, screws, axles).

(d) Shearing.

(e) Transverse straining (beams, girders, joists).

Factors of strength are:

1. Specific gravity.
2. Soundness of tissue.
3. Freedom from branches.

Timber, like any other material, should never be loaded to over one-fourth of its indicated strength.

Transverse strength is always proportioned to length of girder; to width of girder; and to the square of the depth of girder. It is *the* quality of timber which is most required in timber used for building purposes.

VI. Hygroscopical qualities.

(a) Timber changes form, coherence and volume with greater or lesser ease under the influence of moisture, applied in gaseous or liquid form. Hence shrinking, swelling, warping, checking, cracking, casehardening and working.

(b) Water invariably saturates the cell walls; in addition, it may or may only partially fill the lumina.

(c) Sapwood invariably contains more water than heartwood.

(d) Rate of dryness depends on the species, looseness of tissue, dimensions of object to be dried, presence or absence of bark cover in logs, preceding treatment by floating, deadening, steaming, prevalence of sapwood or heartwood, season of year, exposure to wind, climate etc.

(e) Boiling and steaming reduce the hygroscopicity and produce, consequently, a more even shrinkage.

(f) The evaporation from the cross section bears to that of the tangential and to that of the radial section the ratio of 8 to 1 to 2.

(g) In the dry kiln, temperatures of 160 degrees to 180 degrees Fahrenheit are gradually produced. Drying is accomplished by hot air, steam and moving air.

Conifers stand the dry kiln process much better than hardwoods. The better qualities of hardwoods undergo air drying before being kiln dried, especially so in wagon, furniture and barrel factories.

The dry kiln saves insurance and interest on large stocks of lumber and allows the lumberman to rapidly fill pressing orders for lumber.

(h) Wood is least permeable for water in the direction of the tangent or vertically to the medullary rays —a fact important for tight cooperage.

1. Shrinkage.

It is least along the fibre; it is up to 5% along the radius and is up to 10% along the tangent.

Shrinkage of over 5% of green volume

occurs in walnut, linden, beech, elm, chestnut, birch.

Shrinkage of 3 % to 5 % occurs in oak, maple, sycamore, ash, cottonwood, yellow pine.

Shrinkage of 2 % to 3 % occurs in spruce, larch, fir and white pine.

A large percentage of rosin, narrow annual rings and light specific gravity reduce shrinkage within the same species.

2. Checking.

It depends on the rapidity of the drying process; on size and dimension of object; on peeling of logs; on homogeneity of tissue.

Checks are often of a temporary nature, disappearing when the inner layers are as dry as the outer layers.

Hardwoods check much worse than softwoods; and rift sawed or quarter sawed lumber checks less than bastard sawed lumber.

Remedies against checking of logs are: Winter cutting; strips of bark left near the end of peeled logs; felling with the roots and leaving the crown on the undissected bole; deadening; "S" shaped iron clamps driven into logs; boards nailed onto the ends of the logs; earth cover at the ends of the logs; red lead painting for export logs.

Remedies against checking of lumber are: Quarter sawing; slow air drying under sheds; veneer sawing; steaming or boiling; sticks placed close to the ends of tiers in lumber piles.

Checks are radial since the tangential shrinkage is greatest. The so-called wind (or ring) shakes are not caused by the hygroscopicity of the timber; they are merely a form of disease of timber, due to frost, heat, fire or insect plagues interfering with the radial cohesion of adjoining rings.

3. Swelling, warping and working.

These phenomena are due to reabsorption of water after drying. The swelling is greatest tangentially. Heartwood warps less than sapwood, and conifers warp less than hardwoods. Boards obtained from close to the slab warp worst of all.

Remedies against working are steaming; varnishing; forming boards by gluing fine veneers one upon another; allowing framework of doors to be sufficiently grooved for receiving the panels.

VII. Duration of wood.

(a) Duration of wood depends on:

1. The surrounding conditions; i. e., tropics or arid deserts; presence of insects (ants and fungi); contact with clay, limestone or sandy soil; immersion in water (toredo); exposure to atmosphere; moisture conditions; presence of preserving matter (salt water, copper mine water).

2. The natural qualities of wood, especially the presence or absence of rosin, tannin and other preservatives; the specific gravity; the percentage of sapwood; the susceptibility to fungus and insect diseases. Locust, red cedar, sequoia, bald cypress, are less subject to such diseases when dead than when alive.

(b) Remedies against destruction are: Impregnation or painting; charring the part imbedded in the soil; winter cutting; change of species when replacing ties; kiln drying and steaming and smoking; raising buildings high above ground.

(c) Bulletin No. 10 gives the following data for the average "life" of ties:

White and chestnut oak,	8 years
Chestnut,	8 "
Tamarack,	7—8 "
Cherry and walnut,	7 "
Elm,	6—7 "
Longleaf pine,	6 "
Hemlock,	4—6 "
Spruce,	5 "
Red and black oaks,	4—5 "
Ash, beech, maple,	4 "
Locust, cypress,	10 "
Red cedar,	10 "
Redwood,	12 "

(d) Schedule for lumber:

Very durable.	*Durable.*	*Short lived.*
Walnut	Ash	Beech
Locust	Larch	Sycamore
Sequoia	Yellow pine	Birch
Cedar	Spruce	Linden
White oak	Fir	Cottonwood
Catalpa	Yellow poplar	White pine
Sassafras	Douglas fir	
Chestnut		
Longleaf pine		

VII. Heating power.

Heating power or fuel value bears a direct ratio to specific gravity air dry. All wood fibre having the specific gravity 1.56, equal air dry weights of our common species furnish equal heat. On the other hand, light weight means greater inflammability and a quicker heat, which naturally lasts for a short time only. The heating power of hard coal is to that of lignite and to that of wood as 5.2 : 4.3 : 1. In other words, 5.2 lbs. of dry wood yield as much heat as 4.3 lbs. of lignite or as 1 lb. of coal.

Influencing factors are found in the following moments:

(a) Presence of rosin increases the heating power by about 12 %.

(b) A cord of wood containing 45 % moisture has, after German experiments, the heating power of half a cord of air dried wood. After Sargent, the discrepancy is not as great. One cord of green wood contains 250 gallons of water, and the calories of heat required to convert this large amount of water into steam are lost for heating purposes.

(c) Unsound wood has a reduced heating power, the cell walls being decayed.

(d) Chestnut, and to a certain extent larch and spruce, are despised in open fires owing to crackling and emission of sparks. Black gum is despised because it is difficult to split and therefore difficult to season. Hornbeam, birch and alder are said to furnish a particularly quiet flame.

(e) Schedule of the heating power of wood per cord:

Best.	*Good.*	*Moderate.*	*Bad.*
Hickory	Oak	Spruce	White pine
Beech	Ash	Fir	Alder
Hornbeam	Birch	Chestnut	Linden
Locust	Maple	Hemlock	Cottonwood
Heart pine		Sap pine	

IX. Miscellaneous technical qualities of wood.

(a) Adaptability to planing and molding; varnishing and polishing; painting and gluing.

(b) Nail holding power, which is said to be excellent in chestnut, white pine and hemlock.

(c) Twisted growth, which is frequent in chestnut, Italian poplar and horse chestnut. Certain twists are due to a hypertrophical growth of the tissue and are highly prized by the trade under the names of birdseye maple, curly poplar, curly walnut, curly cherry and curly ash etc. It is impossible to say whether a standing tree is "curly" or not. Sap-sucking woodpeckers may start the "freak."

(d) Knots check the value of lumber. A standard knot is a sound knot, the diameter of which varies according to local inspection from 1¼" to 1¾". Dry, dead and unsound knots throw a board into the mill cull pile. Usually, the knotty part of a log is sawn into dimension stuff. The core of a log, even in yellow poplar, necessarily shows knots, since there is no height growth without simultaneous formation of side branches.

(e) The discoloration of the inner layers of certain species which are not classed as heartwoods (beech and maple) is a disease often found in old trees and causes rejection for certain applications in the trades (impregnation).

CHAPTER V. MANUFACTURING INDUSTRIES.

§ XVII. THE SAW MILL.

A. The saw.

Three kinds of log saws are used:

I. Straight saws, viz:
- Vertical straight saw;
- Gang saws;
- Horizontal frame saw.

II. Circular saws, viz.:
- Solid tooth single saw;
- Solid tooth double saw;
- Inserted tooth saw.

III. Band saws, viz.:
- Single cutting band saw;
- Double cutting band saw.

I. Straight saws.

(a) Single vertical straight saw. At the toothed edge this saw has a thickness of from 5 to 10 gauges. Its blade is 8 inches wide and at least twice as long as the log diameter.

A short blade yields the finest work, since it can be spanned more tightly.

The gauge along the back should be finer than the gauge along the cutting line.

The saw can cut any thickness of trees.

The saw cuts only by the down stroke while the log is moved against the saw during the up stroke.

The saw is spanned in a guide frame and is given as many inches inclination toward the log as the feed of the carriage per stroke amounts to. If the saw were not inclined all the work would be done by the lowest teeth.

The usual set is still the spring set and not the swage set, although the latter is sure to be superior.

Usually the ends of the boards are not sawn through but are held together by the "comb," which is finally split with the axe.

In filing mill saws, obtain sufficient pitch of teeth to prevent saw from kicking out of the cut. Too much pitch, however, causes chattering.

Gullets must be kept carefully rounded.

(b) Gang saws. They are used in large mills for inferior logs.

The best make is Wickes Bros.,' Saginaw, Mich. Enormous stone foundations are required.

The saw frame has an oscillating motion which presents the saw to the cut in an easy raking sweep, forcing each tooth to do its full share of the work.

Gang saws are not fed from a carriage. The logs are run through feed rolls, feeding the logs into the saws.

Blades are 6 to 10 inches wide and of 8 to 16 gauge.

Horsepower required is said to be for friction, 3 horsepower; for first blade 4 horsepower, and for every additional blade ½ horsepower more.

Where log heaps (up to 12 logs) are run through the gang saw, the logs are slabbed by a "rosser" or "log siding machine," so that the logs can be placed one upon another.

(c) Horizontal frame saw. It is used to cut fine veneers and valuable timber. Its advantage lies in the fact that very little weight rests on the saw, that the saw can cut on both trips (to and fro), that high speed may be applied and that a thin gauge can be used.

The best make is Kirschner's, Leipzig, Germany.

II. Circular saws.

(a) Power.

Ten horsepower should manufacture 5,000 b. feet per day; 20 horsepower should manufacture 10,000 b. feet per day; 30 horsepower should manufacture 30,000 b. feet per day, and each additional horsepower should add 1,000 b. feet to amount cut. This amount depends on size of logs.

Five horsepower is required for a 20-inch to 30-inch saw; 12 horsepower for a 30-inch to 40-inch saw; 15 horsepower for a 48-inch to 50-inch saw; 25 horsepower for a 50-inch to 62-inch saw.

(b) Right hand and left hand mills.

If the carriage is to the left of the observer while the saw runs towards him, the mill is a left hand mill, and vice versa. A right hand saw is screwed to the arbor by a left hand nut and is usually driven by a left hand steam engine.

Center crank engines can be used for either right or left hand mills.

(c) Speed.

The proper speed at the rim of any circular saw is 9,000 feet per minute.

There should be a speed indicator to control the saw's speed. It costs 75c.

If the power is too light to run the mill at standard speed, portable mill men usually increase the speed of the engine, putting a larger receiving pulley on the saw mandrel.

(d) Proper qualities of a saw.

1. The usual thickness is 7, 8 or 9 gauge. Frequently the center is one gauge heavier than the rim.

2. There should be a sufficient number of teeth for the amount of feed.

Each tooth should cut as much as is offered to it at a revolution.

To cut one inch of lumber one may use either:

Eight teeth, cutting ⅛ inch each at a revolution, or

Sixteen teeth, cutting 1-16 inch each at a revolution, or

Thirty-two teeth, cutting 1-32 inch each at a revolution.

The number of teeth for one inch of feed should be, in hard timber, 16 teeth; in medium timber, 12 teeth, and in soft timber, 8 teeth.

The usual feed is from 1 to 6 inches per revolution. The quicker the feed the more teeth are required to do the work.

3. The saw must be perpendicularly hung; must slip on the mandrel against the fast collar easily, so as not to twist the saw out of true, thus causing it to buckle when the loose collar is tightened up.

The loose collar is hollow at the center (small saws excepted) and has about 6 inches diameter and ¾ inch rim.

By pressing a layer of writing paper between the collar and the saw the saw may be slightly bent toward or away from the carriage.

4. The saw must be evenly set (either spring or swage set). The teeth, filed square (not to a point but to a cutting edge), must form an exact circle and must retain that form in the course of operation.

5. The teeth must have the proper pitch. A shallow tooth cuts the smoothest lumber, but forbids of rapid feeding.

The modern shape of teeth is such as will facilitate filing and as will preserve the original pitch.

A tooth gets dull over as much of an inch as it cuts.

The gullet of the tooth must be larger for soft wood than for hard wood. Large gullets weaken the saw, small ones increase the friction very badly.

A tooth should be filed two to four times a day. The backs of the teeth must never protrude beyond the point.

Gullets must be kept circular carefully. Any sharp edge in a gullet is sure to cause a crack.

6. The mandrel must not heat in the journals. The boxes require frequent rebabbitting. The stem of the mandrel must be exactly level and perfectly straight.

Mandrels run hot owing to excessive friction in bearings, to excessive tightness of belts, insufficient lubrication or heating of the saw in the center.

A hot mandrel expands the saw in the center, causing crooked sawing.

(e) Lining of the saw with the carriage into the log.

The saw must "lead into the cut" just sufficiently to keep the saw in the cut. The proper lead is ⅛ inch in 20 feet. Too much lead into the cut causes the saw to heat at the rim. A lead out of the cut causes the saw to heat at the center.

The ⅛ inch lead in 20 feet is obtained by sighting over the saw and fixing the saw plane for a radius of 10 feet. This may be done by putting two staffs vertically into the ground 10 feet from the saw center behind and in front of the saw; that done, a horizontal stick is fastened to a head block so as to just touch the forward staff. Then the carriage is gigged backward to the other vertical staff where the horizontal stick must lack exactly ⅛ inch from touching.

(f) Filing room.

Automatic sharpeners and gummers are required for mills having over 15,000 feet daily capacity.

Setting instruments for spring set are similar to those used with cross cut saws, constructed either after the wrench principle or after the block and hammer principle.

The spring set is gradually discarded for the swage set.

In swaging use oil on the point of the tooth, after filing to a sharp point. Swaging should draw the tooth out and should not shove it back.

The set or swage of teeth should increase the gauge at the rim by at least 3-32 of an inch.

The pitch of the tooth might be controlled by a so-called trammel.

Gumming is required to preserve the original hook or rake of the tooth as well as the original roundness of the gullet.

Gumming as well as sharpening are usually done with emery wheels.

Emery wheel rules are as follows:

1. Do not put too much pressure on emery wheel so as not to change the temper of the tooth (bluing and casehardening and consequently crumbling of the tooth).

2. Do not try to fix a tooth fully at one time. Treat it gradually at five or six revolutions of the saw.
3. Proper speed for emery wheels at the rim is 4,500 feet per minute.
4. After gumming remove the irregularities at the edges with a side file, since cracks in saw are apt to start from them.
5. Hammering becomes necessary when the use of emery wheels has caused the saw to expand ("let down") at the rim.

For small mills gumming with a file or a butt gummer is preferable to the use of emery wheel.

Soft wood requires more set or spread and less pitch than hard wood.

Swaging is also called upsetting or spread setting.

(g) Inserted tooth circular saws.

1. The insertion into each socket of the rim consists of a holder and of a chisel point. These points are extremely hard; still they can be filed and swaged with the help of specially constructed files. It does not pay, however, to spend much time in filing since new points are cheap, and since they are readily inserted with the help of a special wrench.

Points are oiled before being inserted.

When renewing one individual point be sure to have it dressed down to correspond to the line of old points.

If the saw guide is not properly adjusted it may touch the holder and smash the saw.

2. Advantages of inserted tooth saw are:

Less experience is required for dressing a saw.

Less filing and gumming.

Less saw repairs in backwoods.

Diameter of saw remains unchanged during its use.

3. Disadvantages of inserted tooth saw are:

The saw kerf is very heavy.

The teeth are large and hence few, so that feed must be comparatively slow.

The price of the inserted tooth saw is higher than that of the solid tooth saw.

The best makes are the Atkins and Disston saws.

(h) The double circular saw.

For big logs and high speed a double circular saw must be used.

The width of the widest board which a single circular saw may cut equals radius minus three inches. Hence much valuable material is wasted in the common circular saw mill sawing heavy logs.

The double circular saw shows an under or lower saw of 56 inches or 60 inches and an upper saw of 30 inches or 36 inches diameter. The top saw should have a reversed motion (so as not to throw sawdust into the lower saw), an arrangement which it is difficult to secure.

A hanger top saw can be added readily to any single saw. Both saws should have the same speed at rim.

The top saw should remain inactive so as not to use up power when small logs are sawn.

Inserted teeth are not used at the double mills.

The advantages of the double saw mill are:

1. Less chattering and truer cut than would be possible for one big saw.
2. Thinner kerf.
3. Faster feed.
4. Less expense for saws.
5. Less repairs.

(i) Remarks relative to "putting up" portable circular saw mills:

The minimum yard required is 50,000 board feet.

The expense of tearing down and putting up again is about $50.

For foundation timbers, place two pieces 8 x 10 inches x 11 feet long on either side of the saw pit (3 feet deep) and underneath the "husk." One piece 4 x 6 inches x 7½ feet long is saddled into the two big pieces, spanning the saw pit underneath the far rail of the track.

Construct the carriage track absolutely straight and level on the track ties (16 to 25 in number) and on the saw pit span.

Place carriage with rack shaft, feed and gig works in place and fasten the track by cleats and nails solidly to the foundation timbers. Then place the husk on them at a distance of about 6 inches from the track, putting wedge blocks between the husk and track. Then spike the husk to its foundation—to begin with in two places only, viz.: at the sawyer's corner and at the middle of the opposite side, so as to enable the sawyer to change the lead by wedging the blocks. Then fix or hang the saw, set the saw guide and fire away.

III. Band saws.

(a) The blade.

The blade material is steel. The width of the blade for log band saws is from 10 inches to 16 inches—14 inches being usual.

Gauge of blade is from 19 gauge to 13 gauge.

Under tension of blade is understood the curvature across the width, which is increased or decreased by hammering at center or at edge. The tension gauge with curved edge guides the filer.

(b) The tooth.

Its width is from 1¼ inch to 2¼ inch.

The hook or pitch is from 40° to 65°.

The depth should be as shallow as possible, with gullets kept round, since cracks usually start from a corner in the gullet.

For sharpening the tooth, a medium soft emery wheel should be used and should not be crowded too hard against the saw, so as to prevent case-hardening.

The teeth are swaged—never spring set—like gang saws. The full amount of set should not exceed 9 gauge in a 14 inch saw.

Side filing or side dressing, after swaging, is usually practiced, although objected to by the saw makers.

For gumming, either a gumming press or the emery wheel is used.

(c) The filing room.

Every band saw mill has a separate filing room equipped with automatic dressing machines, i. e., automatic sharpener, automatic swage, automatic swage shaper, saw stretcher etc.

In the band saw mill, the filer is considered more important than the sawyer for the success of the mill.

Saws are changed three or four times a day.

"Brazing" of a band saw means joining the loose ends, uniformly beveled or ground to a feather edge ¾ inch long. A strip of silver solder is placed between the cleaned laps, which are then taken between the cheeks of the brazing clamps heated to a bright red heat. After pressing the clamps together for several minutes and allowing them to cool, the braze is dressed down with a file to the proper thickness.

The filer arrests cracks by punching a small pin hole or dot at extremity of crack.

(d) The wheels.

The band saw runs, belt like, over two wheels weighing from 1,500 to 3,000 pounds (the lower heavier than the upper); the lower wheel driving the upper by the band saw.

The strain on the saw, which should not exceed 5,000 pounds and by which slipping off is prevented, is obtained by raising the upper wheel.

The diameters of the wheels are 8 to 10 feet, the face about 11 inches, the teeth overlapping the wheel.

The crown of the tire is up to 1-64 inch.

The entire length of the log band saw varies from 30 feet to 70 feet.

The saw guides, lined with wood or babbit metal, prevent the cutting part of the blade from bending toward the carriage or toward the wheels, while the guard rolls, standing about 2 inches back of the saw, prevent it from slipping backward at the approach of the log.

The maximum diameter of logs that can be handled by band saws is about 90 inches.

The weight of a band saw mill complete is 20,000 to 40,000 pounds.

(e) The "Allis" double cutting telescopic band saw.

The saw blade has teeth on both edges, so that a board is obtained at each trip of the carriage.

The entire mill is raised or lowered by hydraulic pressure with a view to bringing the top of the logs immediately underneath the upper wheel.

IV. Conclusions.

(a) The superiority of the band over the circular saw lies in a saving of 1,000 board feet in every 16,000 feet of 4/4 inch boards obtained. In heavier planks the saving is less, in lighter boards more. The boards obtained have a better width. Logs over four feet through cannot be handled by circular saws. Further, the band saw allows of a more rapid feed. Hence it is used preëminently for valuable logs, for big logs and for high output.

Frequently mills of large output employ simultaneously band, circular and gang saws, allotting the logs according to their quality, the best to the band saw and the poorest to the gang saw.

Two edgers and one trimmer can take care of such a combined output.

(b) Mammoth mills are now considered uneconomical, since it is difficult to take care of the output of boards at the outlet from the mill floor.

The output per mill hand in big concerns is up to 7,500 board feet daily.

Four acres of mill pond hold up to 1,000,000 board feet.

Two standard gauge trains supply an output of 100,000 board feet from an average distance of 10 miles, daily.

B. The carriage.

I. The composing parts are:

The truck with head blocks, knees, dogs, set works, and the driving machinery.

The carriage is subject to the roughest treatment. Still, its proper alignment is as essential as that of the saw.

(a) The truck is made of timber at least 6 inches square, thoroughly seasoned and strongly braced and bolted.

Construction material is:

Up North—Norway pine, birch and maple.

Down South—Yellow pine and white oak.

The length should correspond with the maximum size of logs.

So called screw block trailers may be added, increasing the length (in longleaf pine mills) up to 72 feet.

(b) The head blocks, iron with steel face, are let into the timbers of the truck and form a groove for the tongue of the knee, which slides on the head blocks, being moved forward and backward by the set works.

The head block and knee form a right angle into which the log is firmly pressed.

(c) The knee is either solid or hollow and carries the dogs.

The dogs are hooks or clamps or teeth, meant to grasp the log. They are fastened either inside or outside of the knee.

Two tooth bars, playing inside the hollow knee and pressed by a powerful lever, replace the original dogs in modern mills.

"Underdogs" are used in quarter sawing.

The number of head blocks, knees and dogs is variable. The minimum is two of each.

(d) The set works consist of:

The set beam, a shaft running underneath the carriage from head block to head block, with a pinion at each head block. This pinion corresponds with a rack forming the tongue or basis of each knee.

The index disc and ratchet.

The set lever, handled either by the sawyer, in small saw mills, or by the setter, in larger mills.

The set works are usually double acting, so that the knees advance with the to and fro motion of the set lever.

In addition, each knee can be moved individually on its rack by the so-called taper movement.

The knees, before a new log is loaded, are receded either by a spring device or, on the gig motion of the carriage, by a friction device.

The brake wheel on the setshaft acts as a buffer when logs are loaded on the car.

(e) The wheels.

The wheels are attached either to the carriage or to the floor. The near wheels are flat on the tire and the far wheels, called guide wheels, are grooved on the tire.

In band saws, an automatic off-set is required to prevent the face of the log from striking the saw on the gig motion.

The steel rails are invariably placed on stringers.

II. Driving machinery.

The to and fro trips of the carriage are known as feeding and gigging.

In small mills the motive power is derived from the saw arbor by:

(a) Rack and pinion device.

(b) Chain, rope or cable running over one or several sheave drums.

The speed is regulated either by so-called cone pulleys (two, three or four on the same shaft) or by a paper friction device.

The so-called Reamy Disc Friction allows of freely varying the speed.

The usual feed, with the cone pulley, is from ¾ inch to 3 inches per revolution of saw.

In large saw mills the piston of a steam cylinder pushes the carriage to and fro (so-called shotgun feed). In that case the carriage usually runs on three rails (center guide rail).

C. Additional parts of high grade saw mills:

I. "The log haul up" (elevator) consists of a flanged foot wheel and an inclined trough, on the bottom of which runs a strong endless chain driven by sprocket wheels. The chain has steps (called welds) at intervals of about 6 feet.

The haul up is driven by a separate engine or from the main shaft by double gear wheels. It consumes a great deal of power.

At the upper end of the haul up, a log flipper "boxes" the logs out of the trough onto the log deck, which is usually inclined toward the carriage.

On the log deck, the logs are freed from dirt and bark by hand.

II. "The nigger," handled by the sawyer, throws the logs on the carriage and turns them by a boxing movement.

III. "The hog" is a steel box within which the edgings and trimmings are cut into small slices by very strong knives rapidly rotating.

IV. "Dust conveyors" convey the output of the hog and the sawdust automatically to the boilers.

D. The edger.

The boards, falling from the log, are conveyed automatically or by hand to the edger.

I. Parts of the edger are:

(a) One or several circular saws of 12 inches to 28 inches diameter.

(b) Feed works, either power or hand driven, consisting either of a carriage or of feed rolls or of barbed chains by which the boards are fed into the saws.

(c) Edger table.

II. Task of the edger is:

(a) Removal of defects, knots, bark edge at the side of a board.

(b) Splitting boards into pieces of different quality.

(c) Rapid sawing to proper width required for special purposes.

III. Kinds of edgers.

(a) Hand feed edger, with one or two saws.

(b) Power feed edger, usually with a single saw.

(c) Gang edger.

IV. Pointers.

(a) The distance between the various saws in gang edgers is regulated by overhead levers or by hand wheels.

(b) Several boards can be fed at one time.

(c) The attendant of the edger must be a lumber inspector at the same time, so as to turn out the maximum value of edged product.

(d) The boards are taken to the edger from the live rolls onto which the board drops from the log, either by hand or automatically, by chain conveyors.

(e) The boards are conveyed from the edger to the trimmer by hand.

E. The trimmer.

In large mills, trimming follows edging. In small mills, edging follows trimming.

I. Parts of the trimmer are:

(a) One or several circular saws about 18 inches in diameter. A one saw trimmer is called a "cut-off."

(b) Feed works, viz.: live rolls or carriage or barbed chains running over sprocket wheels.

(c) Table.

II. Task of the trimmer is:

(a) The shortening of boards to standard lengths of 6, 8, 10, 12 and up to 20 feet, allowing 2 inches extra for shrinkage.

(b) The removal of defects at either end, so as to raise a board into a higher grade.

(c) The cutting of straight ends.

III. Pointers.

(a) Where two saws are used, the distance between them is changed by a lever or by a screw wheel, shifting one of the saws, while it is in motion, along the shaft.

(b) Chain power fed trimmers are used in all large mills. The saws are either jump saws, easily pushed from below the table in pairs, or swing saws, hanging above the table and, similarly, pressed down by the attendant in pairs by a touch on hand or foot levers.

F. Yard work. (Sorting and piling.)

I. Sorting.

The board after leaving the trimmer is taken up by a chain or cable conveyor and passes by the lumber inspector, who pencil-marks its quality.

The various qualities are either at once thrown into parallel gutter conveyors, leading to separate chutes, below which a wagon or truck is in waiting, or are transferred to the piles by endless chain conveyors, by hand trucks and wagons. Frequently elevated roads traverse the yard on which and below which such conveyance takes place.

II. Piling.

Strong, high, horizontal ground sills are of the utmost importance. The front sill should be higher than the middle and back sills, except in shed drying.

In some yards the front of the piles is given an overhanging "batter," to protect it from rain, an arrangement feasible only in low piles. The usual pitch of the pile is 1 foot in 10 feet or more.

The tiers of boards are kept apart by three or four well seasoned cross pieces called sticks—sawn 1 inch square and placed directly one over the other.

The usual width of the piles is from 6 feet to 10 feet.

The distance between the piles is at least one foot and should be three feet.

In order to prevent end cracks, the sticking should be placed exactly at the ends, slightly projecting over the ends.

Each pile must contain equal lengths, as "overlaps" are sure to get spoiled.

Valuable wide boards are often painted at the ends.

Oak, ash, hickory and elm require at least four months for air drying; lynn, poplar and pine about two and a half months.

Slow drying involves a loss of interest, large yard room, large insurance and slow filling of orders. Still in the case of high grade hardwoods, the use of the dry kiln is disastrous to the lumber.

Thin lumber does not check as badly as thick lumber. Squares check worst of all.

A fermentation and incidentally a discoloration takes place where two fresh sawn surfaces touch one another.

Each pile should have a roof 12 inches high in front and 6 inches high in back, projecting in all four directions over the pile.

Proper curing of lumber is as important as proper sawing of lumber.

III. Dry kiln.

A dry kiln consists of
- shed with gates closing tightly;
- lumber conduit;
- heating apparatus.

The heat is supplied—slowly—
- either by a hot air fan;
- or by a system of steam pipes;
- or by steam admitted into drying room.

The air in the dry kiln must be kept in constant movement, so as to prevent unequal drying of the lumber in the piles.

Lumber can be more evenly dried by steam than by hot air.

Sapwater heated to boiling point expands 600 times. Consequently, wood at 212° F. contains only 1/600 of the water originally found therein.

Before building a mill be sure to consult insurance companies, submitting mill plans.

The insurance company prescribes the distance between the yard, boiler house, engine house, mill and dry kiln. The rate of insurance on a mill is 5% and over.

§ XVIII. WOODWORKING PLANT.

A. Planing (surfacing, dressing or sizing).

The planer consists of cylindrical cutter heads carrying two to four knives and making 3,000 to 5,000 revolutions per minute. It is preferably belted at both sides.

The smaller the diameter of the cylinder with its knives, the smoother is the planing.

The feeding is done either by two to four feed rolls (above) and friction rolls (below) or by a traveling bed. The entire cutting length of the knives should be uniformly used.

The top cutter should do the heavier work in double surfacers.

The knives are usually sharpened automatically.

Lumber is fed into the machine at the rate of 20 feet to 150 feet per minute. Hardwoods more slowly than the soft woods.

The chip breaker is merely a front pressure bar preventing long splinters from being torn off.

Price of single planers is $100 to $400; of double planers $400 to $800.

No machine should have wood in its construction.

B. Flooring.

The flooring machine is a surfacer having an additional outfit of two side cutters revolving on ratchet spindles, cutting tongues and grooves.

The machines weigh 5 tons and more.

The usual flooring made is hard maple.

Planers and flooring machines must be provided with a folding hood connected with an exhaust fan, so as to prevent the shavings from clogging up the machinery or from pressing themselves into the planed surface.

C. Resawing.

Resaws are either circular or band resaws.

The use of a resaw involves a great saving, since it takes a very fine kerf and at the same time relieves the work of the main saw.

The feed is automatic and consists of four rolls.

Circular resaws have as low as 19 gauge at the rim and are frequently built as segment saws.

D. Ripping.

The rip saw is a circular saw running on a bench and allowing, by a gauge arrangement, to cut any desired width of board or strips. It is usually hand fed.

A power fed gang rip saw is merely an edger.

E. Cut off saws.

Cut off saws are either swing saws, jump saws, stationary saws with carriage moved by hand or automatically, or traveling railway cut off saws when the saw is moved horizontally against the timber.

F. Sand papering.

I. Belt sand papering, for carriage spokes, axe handles, buggy poles etc.

II. Disc sand papering, notably for boxes.

III. Spindle sand papering, for small tool handles.

IV. Cylinder drum sand papering.

The object to be sand papered is always fed onto the machine by hand.

G. Scraping.

Under "scraping" is understood the removal of an extremely thin (not over 1/64 inch) layer of tissue from a planed surface. It is meant to replace and to cheapen the process of sand papering, and is not intended to reduce the thickness. The scraper consists of power driven, smooth feed rolls and of one stationary knife, over which the boards are passed. Corky or stringy lumber cannot be scraped.

H. Mitering.

In mitering the stock is run along the so-called "fence" against a circular saw, the plane of which forms a variable angle with the plane of the saw table.

I. Moulding.

Mouldings are either one, two or four sided.

Cutter heads, into which cutters of variable size and form are inserted, secure any variety of patterns of moulding. Moulders are often called "stickers."

J. Miscellaneous.

Under "matching" is understood the cutting of a tongue and groove into the edge of box boards, flooring boards etc. The work is done by a knife and cutter head.

Under "gaining" is understood the ditching across a piece.

Under "plowing" is understood the ditching along a piece.

"Tenoning" is especially required for doors and blind slats—single and double tenons being distinguished.

Door panels go through a "panel raising" machine.

Sash and door "relishing" means the biting or sawing of large teeth into the tenon.

§ XIX. VENEERING PLANT.

Veneers are either sawn or peeled (sliced). The furniture factory and the package trade use veneers, with entirely different ends in view, on a daily increasing scale.

The thickness of sliced veneers ranges down to 1/120 inch; veneers less than 1/40 inch thick, however, are rarely used.

Sawn veneers are 1/20 inch thick or thicker.

A. Veneer saws.

Any saw of a fine gauge is a veneering saw. Largely used are the:

I. Horizontal mill saw;

II. Fine band saw;

III. Circular saw ground to a fine gauge (19 gauge) at rim, strong (5 to 10 gauge) at center; there is only one collar, to which saw is screwed. Veneer saws consisting of sections screwed to a common centerpiece are common.

B. Veneer cutting machines.

Logs are boiled or steamed (in exhaust) for several hours beforehand. Usually, logs 3 to 5 feet long are used, the length of the log almost equaling the length of the knife.

I. The rotary machine peels any log of, say, over 18 inches diameter, notably poplar, lynn, gum and cottonwood, into thin layers by revolving the log slowly against a sharp stationary knife. A clipper cuts the roll into pieces of proper size for strawberry boxes, staves, potato barrels, box boards, furniture backing etc. The core of the log, some 6 inches in diameter, does not allow of peeling.

II. The stationary log cutter consists of a knife set in a sash frame removing at each stroke a thin slice or board.

C. Advantages of veneering.

I. There is little or no loss of timber for kerf and sawdust. Valuable logs (for furniture, cigar boxes) are invariably veneered nowadays. Logs too short for lumber are fit for peeling.

II. Veneers show little shrinkage and little checking. Hence they allow of rapid seasoning. For that purpose, the veneers are frequently passed between heated rollers.

III. The rotary machine yields very large veneers often entirely free from knots which are merely contained in the core left unpeeled.

§ XX. BOX FACTORY.

A. Kinds of boxes.

(a) Planed or unplaned.

(b) Knocked down or set up.

(c) Nailed, lock-cornered or dovetailed.

B. Material.

Wood as light as possible—readily planed, nailed and treated.

The best is white pine; next are spruce, basswood, poplar and, more recently, yellow pine, hemlock, gum, cottonwood. Elm and sycamore are used for special purposes.

C. Machinery.

A well equipped plant contains planers, resaws, rip saws, cut off saws, box board matchers (which tongue and groove composite sides), lock corner machine (or nailing machine or dovetailing machine), sand paper machine and printing machine (drum pattern).

D. Business side.

The skill of the box maker is shown by working up, without waste, the proper proportions of widths and thicknesses. Careful piling of lumber in the yard, separating according to width and thickness, is very essential.

The interdependence between crop prospects and box prices is easily felt by the box makers.

For large boxes the nailed pattern is preferred, being the strongest. Box shook fasteners and box strapping increase the strength.

The lock cornered box is preferred for starch, plug tobacco and small boxes. Lock cornered boxes are required either by the bad qualities of the lumber or by the quality of the stuff packed. Locked corners demand gluing. "Bevel locked" corners and "inclined locked" corners are scarcely used. The dovetailed box does not require gluing. The mechanical process for stamp locked corners (dovetails stamped into thin boards) is not yet perfected.

E. Expense of manufacture.

I. The manufacture of 1,000 feet of lumber into shooks involves a bill of $4 for labor and $1 for wear and tear.

II. One thousand small lock cornered boxes—9x6x3 inches, ¼ inch thick for frame and 3/16 inch for top and bottom—require 700 board feet of lumber worth $8.50 in case of white pine; $5.10 for labor; $2.72 for glue, wear and tear; $2.50 for ten packing crates.

§ XXI. BASKETS.

A. Willow baskets.

They are hand made, mostly from cultivated shoots of Salix viminalis, amygdalina and caspica. Shoots 1 to 2 years old are used, being cut either in fall or in spring. In the first case, the bundles of shoots are kept in water over winter. The shoots are peeled after the rising of the sap by being passed through an iron or wooden fork; then rapidly dried to retain the white color. In this condition the material may be stored away for years. The shoots are bathed in water before weaving to restore flexibility and toughness. The bottom of the basket is made first, and then, frequently with the help of a model, the standards or uprights of the wall are fixed. The manufacture has been introduced into New Jersey and New York.

B. Wooden baskets.

They are used for picking and transportation of bulky farm produces. Sizes ½ bushel to 2 bushels.

I. The hand made basket, from thin strips split and shaved from basket oak and white oak (sapwood).

II. The Briggs stave basket consists of radial ribs cut from 2¾ inch oak planks; cross cut into lengths varying from 12⅝ inch for ½ bushel to 18 inches for 2 bushel baskets. The ribs are jointed and pointed to an exact fit for a round center plate and then bent over a model form having grooves indicating the proper position for each rib and for the strong elm hoop clasped around the rim.

III. The common wood basket is made of straight long ribs up to ¼ inch thick, cut on a rotary veneer machine. No center piece, no pointing and no jointing are required. The ribs are bent over a model form. A workman is said to make about 300 baskets in a day.

§ XXII. COOPERAGE.

A. Terminology.

I. "Slack" cooperage turns out barrels for packing lime, vegetables, cement, salt, nails, crockery, sugar, flour, etc.

II. "Tight" cooperage deals with barrels for liquids and for meat (pork).

B. Material used:

Any species may be used for slack cooperage. Alcoholic liquors must be cased in white oak (Quercus alba, michauxii, prinus, macrocarpa, minor etc.). Red oak will not hold whisky, but is used for other staves, flour barrel heading, sawn and coiled hoops.

White ash is used for pork staves and butter tubs.

Elm yields the best coiled hoops and the best slack staves.

Cottonwood and gum are cut for staves on a large scale.

Chestnut is used for cheap slack barrel hoops; yellow poplar for tobacco hogsheads; basswood for flour barrel headings; beech and maple for sugar barrels; second growth of hickory, birch and ash for hoops.

For buckets, red and white cedar; for tanks, cypress and redwood are preferred.

C. Specifications:

I. Flour barrels contain 196 pounds, or 3.57 bushels, or 32 gallons of flour.

The diameter of the head is 17 inches; the length of the staves 28 inches.

The forms preferred in slack cooperage, either locally or for given goods, vary to such a degree that figures descriptive of the forms cannot be recorded.

II. The "Tight Coopers' Union" specifies:

(a) Whisky barrel staves—length 34 inches to 35 inches, thickness ⅞ inch, width 4¼ inch after jointing, measured across bilge on the outside.

(b) Wine barrel staves—length 34 inches, thickness 11/16 inch after drying and planing, width 4½ inches.

(c) Oil, tierce and pork staves have similar dimensions, allowing, however, of sap, one or two sound worm holes and knots showing on one side only.

Variations of ⅛ inch in length and 1/16 inch in thickness are permitted in all staves (so called equalized staves).

Pipes, butts and puncheons contain over 100 gallons and are used for port, rum etc.

A hogshead of claret is 46 gallons.

D. Statistical notes:

I. One thousand feet board measure in logs—Doyle's rule—yield 2,500 sawed flour staves, 3,200 veneered staves, 4,000 cut hoops or 3,000 sawn hoops.

II. One cord of bolts, with the bark, will make 1,000, or, without bark, 1,200 slack staves.

III. In Tennessee, eight white oaks (of over 18 inches diameter) are said to average 1,000 half barrel beer staves.

E. Prices and their tendency:

	Apr. 1, 1901.	Feb. 10, 1904.
Staves—		
No. 1, flour barrel, per 1,000	$ 9.00	$11.00 to $13.50
No. 1, cottonwood, per 1,000	6.00	....
No. 1, gum, per 1,000	....	10.00 to 12.00
Memphis white oak, without sap	26.00	44.00
Heading—		
No. 1, flour barrel, per set	.05½	.08 to .08½
No. 1, gum, per set	.04	.07½ to .08
Hoops—		
Coiled elm hoops, per 1,000	7.00	9.00 to 10.00
Hickory hoops, per 1,000	6.00	6.25 to 6.75
Barrels—		
Flour, 12 hickory hoop barrel	.41	.45 to .48½
Flour, 8 patent hoop barrel	.39	.46
Flour mugwump (10 hickory hoops)	.39	.45
Oil (52 gallon)	....	1.45

The price of white oak material has risen rapidly and must continue to rise indefinitely, substitutes for white oak being impossible.

In slack cooperage, on the other hand, raw material continues to be plentiful, and new, cheaper forms of packages enter into daily competition with the barrel.

The cost of making tierces at Chicago is: Staves ($21 per 1,000), 39 cents; heading, 16 cents; hoops, 20 cents; wages, 25 cents; total, $1.

F. Manufacture of heading, staves, hoops and barrels.

I. Heading.

Heading for tight cooperage is sawn from split bolts. These bolts are obtained in the woods by halving, quartering and splitting (by hand and always with the grain) round blocks which slightly exceed in length the diameter of the heading. The heart of the bolt is not removed. The bolts are wagoned or sledded to the heading plant, where they are inspected, sorted, piled and air dried.

Twenty-five horsepower are said to be required at a heading plant. The output at a "setting" of the plant averages 200,000 sets of heading.

The tight heading plant usually contains a sawing machine, an equalizer and jointer.

(a) The heading sawing machine consists of a vertical circular saw (44 inches diameter) screwed to the arbor without a loose collar; a pendulum swing with "grate" and "dogs" to receive the bolt; a slide guiding the swing; a gauge, adjusted by screws; a separator throwing the sawed slats to the side. Price $300.

(b) The equalizer contains a tilting table or a carriage, which is forced against a pair of circular saws.

(c) The jointer edges the slats. It consists of a strong wheel carrying on its side 4 to 6 straight knives. The wheel is covered by a hood. Price $140.

For tight cooperage the joints are made secure by blind wooden nails and by coopers' flag (Typha latifolia) glued into the joints.

Two more machines are required to finish the heading prepared by the apparatus mentioned under a, b. and c, viz.:

(d) The heading planer carries knives 16 inches to 24 inches wide and has a capacity of 8,500 headings a day.

(e) The heading turner cuts the heading circularly and carves the required bevel edge. It usually carries a concave saw, to cut through the boards, and on the same mandrel a small, thick circular saw which gives the bevel.

The heading, held in clamps, rotates obliquely against these saws. Price $235. Capacity 5,000 a day. Heading is usually kiln dried.

For slack heading, quarter sawing is usually not required. Ordinary lumber can be used. The slack heading plant may or may not contain all of the machines enumerated under a, b, c, d and e.

The tight heading plant of the woods contains the machines a, b and c, while the machines d and e are usually combined with the cooper works, unless they form a separate establishment.

II. Staves.

(a) Staves for barrels containing the more valuable beverages are hand made (rived staves). The riving of staves wastes timber. Proper bilge and curvature are obtained either by hewing (Germany) or in the finishing plant (America).

The white oak timber used must come from straight trees of over 18 inches diameter. Such trees are found in clumps only. Hence the necessity of a portable finishing plant, using from 15 to 35 horsepower. At each set or site—now usually 15 miles from the railroad—at least 100,-000 staves are manufactured. Six hundred rough staves have the weight of 1,000 finished staves. Hence it is wise to bring the plant close to the timber.

The felled tree is sawed (by hand) into blocks of two inches more than stave length, which are placed on their larger ends. Then the sap line is demarked with a pencil, and inside the sap line, with the help of a pattern showing the cross section of a stave, as many staves are pencil-marked as possible.

By axe, wedges and wooden mauls the block is then halved and quartered (and rehalved and requartered in case of heavy blocks), the clefts following the pencil marks. The sectors are then split, along the annual rings, into rough staves—always following the pencil marks.

The core of at least four inches diameter, containing the small limb-stubs, is thrown away.

The rough staves are inspected and sorted and piled hogpen-fashion for air drying, either before or after sledding or wagoning to the finishing plant. It might be added here that this finishing plant is—contrary to expectation—never combined with a heading plant.

(b) The "stave bucker," by which three-fourths of all rived staves made in the United States are refined, dresses and planes both sides of the staves to proper curvature and bilge. A rack forces the rough staves through the narrow passage left between two knives (either straight knives, or curved to correspond with the periphery of the finished barrel) which are fastened in a rocking frame.

(c) The "stave dresser" frequently takes the place of the bucker. It carries knives on two cutter-heads, dressing and hollowing the stave on both sides to proper thickness and leaving either an abrupt or a gradual shoulder

(d) The stave saw yields staves of equal form, but greater permeability, more economically than the hand. Stave bolts must have the following minimum dimensions: thickness with grain 5 inches; width close to heart 3 inches.

The bolts are barked and hearted in the woods, being split from logs having at least a diameter of 15 inches inside the bark.

The stave saw consists of:

1. A hollow steel cylinder, having the diameter of the barrels to be made and carrying saw teeth at one end.
2. A carriage with clamps passing the saw cylinder.
3. A stave holder running into the cylinder and removing the sawed staves. Capacity 12,000 staves per day.

(e) In slack cooperage, a stave cutter is often used, consisting of a circle (20 inches for fruit barrels) with one knife attached, making 150 revolutions per minute. The stave bolts are steamed beforehand. The knife separates at each revolution of the circle, or by each single stroke, a stave from the bolt.

Capacity 140,000 per day. Price $130. Horsepower, 4.

(f) The rotary veneer machine is now also used to cut 4 inch or 4½ inch gum staves.

(g) The stave equalizer trims the ends and gives the staves the proper length. It consists of two circular saws and a tilting bed or a carriage.

(h) Stave listers or jointers edge the staves in such a way that the edges coincide with a plane through the axis of the barrel.

Staves for export are straight listed and without bilge.

The stave jointer is either a circular swing saw or it consists of two circular saws; or of a number of inclined knives held by cutterheads; or of one knife running in a sash frame; or it resembles a heading jointer (starjointer).

(i) In the "stave planer," a steel pattern passing through the machine with the stave lifts the cutters in such a way as to allow the shoulders of the staves to retain a greater thickness than the middle of the staves.

III. Hoops.

In tight cooperage, steel or iron hoops are used, driven over the barrel by hoop drivers or trussing machines and sometimes fastened by hoop fasteners.

In slack cooperage, wooden hoops are still preferred and wire hoops are only occasionally used. Wooden hoops are either hand made, especially the long white oak hoops used on tobacco hogsheads, or sawed from plank by a hoop machine, or finally knife-cut on a rotary machine or a sash frame machine.

A machine by which sawed hoops are obtained directly from logs does not seem to be much used. By special machinery hoops are planed, pointed, lapped and punched.

A hoop coiler rolls the hoops into bundles; usually the outfit of a "sawed hoop" plant consists of a saw bench, a saw machine and a coiler.

IV. Barrels.

Putting up a barrel requires:

(a) Heating, in order to increase the flexibility of the staves held together by an iron form and by one or two hoops.

(b) Bending in an apparatus consisting of screw and rope, windlass and rope, or of a funnel press.

(c) Crozing, i. e., making a groove for the insertion of the heading, either by a hand planer or by a power groover.

The finished barrel is automatically planed on the outside; if it does not assume the exact form of a doubly truncated parabolloid, it is pressed into shape by a barrel leveler.

§ XXIII. WAGON WORKS.

A. The raw material must be tough and strong and, above all, air dry. The dry kiln often follows after two or three years of air drying.

Second growth of black or shell bark hickory is used for tongues, shafts, spokes, rims, axles, neck yokes, whiffletrees and eveners.

White oak or burr oak is used for spokes, tongues, bolsters, hounds, reaches and axles.

Black birch, rock elm, white oak and locust are used for hubs.

Wagon beds are made of yellow poplar, pines, cottonwoods, the composing boards being either ship lapped or tongued and grooved.

White ash, bending easiest and best of all woods, is used for rims, bent seats, bent bows, shafts etc.

B. The manufacturing machinery is usually supplied by the Defiance Machine Works, Defiance, Ohio.

I. Hubs are cut direct from log to proper length by double equalizing saws and are turned on outside automatically on a lathe; bored for boxes (thimbles); chisel mortised for spokes; and set with two to four iron rings.

II. Spokes are obtained from bolts by rip sawing into squares which are turned on a lathe; tenoned at the big end; equalized in length; sandpapered and polished; and driven into hubs by automatic hammers.

III. Rims and felloes are either bent to proper form or sawn from straight bolts. In the first case, the bolts are steamed or boiled; then bent and pressed in an iron pattern when hot; then cased up and dried; then bored to receive the spokes; rounded on the inside with a slight elevation left around the hole; planed and finally sandpaper polished.

Very wide plank is required for sawn felloes, which are obtained either by a set of concave saws, having the required curvature, or by a narrow band or scroll saw which follows the pencil marks of a pattern made for each piece on the plank.

IV. Axles are turned on a lathe according to a steel pattern spanned in the lathe; are gained to receive bolsters and hounds; and have the thimble skeins driven on by hydraulic pressure.

V. Shafts and poles are sawn from plank 1½ inch to 2½ inch thick and 8½ to 12 feet long; are heated and bent, cased, dried, rounded and belt polished.

C. Few establishments make entire wagons. Usually shafts, spokes, rims, axles etc. are made in factories close to the woods, while other factories closer to the cities or to railroad centers put the wagons together after buying their component parts.

§ XXIV. SHINGLE MILLS.

A. Material.

Breasted, shaved, rived or rifted shingles (meaning hand made) are used in the backwoods only. At Biltmore, shaved shingles made of chestnut cost $2 per M., while so called boards, two feet long and six inches wide, split from white oak, cost $3 per M.

Shaved shingles cannot be laid so neatly as sawn shingles.

For machine made shingles are used:

On the Pacific coast, red cedar;

In the Lake States, white pine, white cedar, spruce, norway pine and hemlock;

In the South, cypress, longleaf pine and shortleaf pine.

B. Durability.

The durability is said to be for:

White pine rived, 20 to 35 years.
White pine sawn, 16 to 22 years.
White pine (sappy) sawn, 4 to 17 years.
Chestnut rived, 20 to 25 years.
Cedar sawn, 12 to 18 years.
Spruce sawn, 7 to 11 years.

C. Specifications.

The usual size of sawn shingles is: 16 inches or 18 inches long; 4 inches wide; 1-16 inch thick at small end; ½ inch thick at butt end. A bundle of shingles contains 250 pieces, is 20 inches long and has 24 tiers.

A carload of white pine shingles, weighing 22,000 pounds, contains 70,000 16-inch shingles; a large car of red cedar shingles contains 170,000 pieces.

One thousand shingles cover 100 square feet of roof, each showing 14.4 square inches to the weather.

A rule for the number of shingles required for a roof is: ascertain number of square inches in one side of roof; cut off the last figure, and the result is the number of shingles required for both sides of the roof. In this case, each shingle shows 20 square inches to the weather.

Shingles are usually laid to show 4 inches of their length, which arrangement yields, in 16-inch shingles, a quadruple layer of shingles on the roof. The higher the grade of the shingles, the larger is the weather face permissible.

D. Machinery.

The machinery used in a shingle plant consists of:

I. Drag saw, either driven from a countershaft or acting directly from the piston, cutting the logs into shingle lengths.

II. Bolter, a circular saw cutting the round blocks into bolts, the thickness of which equals the width of the shingle. Bolts split with an axe yield a better grade of shingles but cause a large waste of timber. A knot saw may be used after bolting to remove knots, rot, sap etc.

III. Shingle machine, constructed in a variety of forms:

(a) A knife is spanned in a sash frame moving up and down and severing a shingle at each stroke from steamed bolts. This system, furnishing "cut shingles," is not much used.

(b) The shingle saw machine uses a circular saw lacking the loose collar and screwed onto the fast collar. The gauge at the center of the saw may be very heavy while the gauge at the rim is from 15 to 20 only.

The shingle blocks are fastened into either a sliding frame or a rotating frame and are tilted continuously, so as to alternate edge and butt cuts. The sliding frame is either hand fed or power fed. A machine takes from one to ten blocks at a time.

IV. The jointer is meant to give a rectangular shape to the shingle. It is either a single or a double rip saw (two saws 4 inches apart) or a wheel jointer consisting of a steel wheel carrying, close to the circumference, 4 to 8 knives radially or almost radially set and of a hood covering the machine and connected with a blowpipe to remove shavings. The shingles are placed opposite an opening in the hood and pressed by hand against the knives, which make about 500 to 800 revolutions per minute.

V. The shingle packer, used for 16 inch and 18 inch shingles, consists of a bench and two slotted and overhanging steel rods. The attendant, pressing the rods down by hand or foot, packs the shingles tightly with their fine ends overlapping.

VI. Shingle planers, fancy butt shapers and dry kilns are found in up to date plants. After dry kilning, bundles require tightening up.

§ XXV. LATH MILL.

The usual length of laths is 4 feet; the weight per 1,000 is 500 pounds. One thousand laths cover 70 square yards, and a cord of slabs yields 3,000 laths.

All softwoods, further yellow poplar, cottonwood and linden form the raw material for lath.

The machinery used consists of:

A. Slab resaw, by which the last board is cut out of the slab. It contains a circular saw and feed works pressing the slab in to the saw.

B. Lath bolter, consisting of a single or double cutoff.

C. Lath machine, which is either an ordinary rip saw having up to six small circular saws and an automatic feed, or a cutter-head and knife machine. The latter machine makes the so called "grooved" lath.

D. Lath bundling machine, which presses the laths together by a foot or hand lever and facilitates binding.

§ XXVI. CLAPBOARD MILL.

The cross section of clapboards is either square or, more usually, beveled, with the big edge from 3/8 inch to 5/8 inch thick.

They are manufactured either from boards 1 inch thick fed through a resaw, the feed rolls of which are inclined toward the saw, or by special clapboard machinery directly from the log. Logs, in the latter case, are cut in pieces of proper lengths (4 feet to 6 feet) by a drag saw;

are turned on a lathe and then spanned into a sliding frame (between pins). Frame and log pass a circular saw with and not against the rotation of the saw. After passing, the log is automatically turned by an angle corresponding with the bevel of the clapboard.

This process leaves a four inch core unused.

A planer, molder or jointer dresses the sides and a butter or trimmer dresses the ends.

§ XXVII. NOVELTY MILL.

Novelty mills have sprung up, in recent years, all over the Northeast, manufacturing trays, wooden dishes, wooden wire, rules, pen-holders, flasks, skewers, toys and thousands of playthings of the hour.

The variety of the raw material used is as great as the variety of the goods manufactured. Still, birch seems to be the acknowledged leader for novelty makes.

Wooden dishes and wooden wire may deserve particular mention.

A. Wooden dishes.

I. Material.

Yellow poplar is used for large wooden trays. Second growth white pine (cuts taken between whirls) is said to be used in New England. Maple is preferred for small oval wood dishes, turned out by a special machine automatically.

II. Manufacture of oval dishes.

These oval dishes are obtained from sawn blocks, scaling from 6 inches by 8 inches to 7¼ inches by 9½ inches.

The dishes are cut with the grain from the side face. Blocks are thoroughly boiled. The cutting knife, revolving circularly, makes 25 dishes to the inch and 75,000 per day.

Two facing knives shave the block clean between every two cuts, carving out true edges.

A screw fed carriage automatically feeds the block into the knives. No skilled labor is required. The attendant merely removes the remnants of a spanned block and places a new block in the carriage.

B. Wooden wire.

Wooden wire is used for mattings, screens, inner rack of ladies' hats etc.

The raw material consists of willow, basswood and poplar plank.

A series of planing knives, in the form of sharp rimmed, fine steel cylinders, plies in a sliding frame over the plank, severing at each stroke a series of wires having the length of the plank.

A straight planer knife follows in the wake of the fine cylinders, removing the irregularities left on the plank.

§ XXVIII. MATCHES AND THEIR MANUFACTURE.

Wooden matches are either round or square.

A. Round matches are made on a machine resembling the wooden wire machine described in Section XXVII.

B. Square matches are made from blocks 16 inches to 24 inches long which, after steaming or boiling, are peeled on a rotary veneer machine into layers having the thickness of a match.

  I. The veneers are automatically clipped into sheets having a length of 6 feet and width equaling 5 to 12 match lengths. These sheets are heaped up in packs containing 50 to 60 tiers.

  II. A knife system, with vertical spur-knives, plays in a vertical sash and cuts from each tier, at each stroke, 5 to 12 matches. The pack, after each stroke, is moved forward the thickness of a match. The machine has a daily capacity of 25,000,000 matches.

  III. The matches are then dried and cleaned by sifting.

C. The treatment thereafter is identical for round and square matches, consisting of the following operations:

  I. Causing the match pegs to lie parallel, by rocking them in an oscillating drawer.

  II. Fixing about 2,250 matches at a time in a clasp or frame.

  III. Dipping the clasp (for fine matches) wholly into paraffine and the tips thereafter into a chemical compound (mastic) which forms the inflammable head. The mastic consists of one or more oxidizing substances (chlorate or bichromate of potash), often mixed with a particle of some explosive, so as to allow of ignition by friction on any rough surface.

D. The raw material for matches is derived from cottonwoods, linden, sapwood of yellow poplar, white pine, spruce. A white, soft and long fibre is required.

§ XXIX. SHOE PEGS AND THEIR MANUFACTURE.

A. Wooden shoe pegs are used to fix the "uppers" to the shoe sole and to construct the heel. The pegs are automatically fed from a pegging machine.

Pegs are ⅜ inch to ⅞ inch long, square with a prismatic head.

The raw material consists of birch and hard maple.

B. Manufacture.

  I. The blocks are cut into discs, ⅜ to ⅞ inch thick, by a circular saw.

  II. The discs are pointed in a pointing machine, which plows parallel grooves, lengthwise and crosswise, into the discs.

  The distance between two furrows equals the width of the peg.

III. The splitting machine severs, by the gradual strokes of a knife (first stroke down to ½, second stroke down to ¾ of thickness of disc), the disc into strips of pegs and, playing crosswise, into individual pegs. After each stroke of the knife the disc is moved toward it by the width of one furrow. During the operation the disc is held in a leather frame.

IV. The wet, red pegs are then bleached by applying sulphuric acid; then dried in heated drums; then cleaned from splinters and irregularities by sifting.

§ XXX. EXCELSIOR MILL.

A. Grades of product.

First Grade—Fine wood wool, thickness from 1/500 inch to 1/64 inch.

Second Grade—Common fine wood wool.

Third Grade—Mattress stock.

The greatest demand is for stock 1/100 inch thick and from 1/32 to 1/8 inch wide.

B. Usage. Excelsior is used for upholstering and for packing (glassware, furniture, confectionery etc.). It is preferred to straw owing to its greater elasticity and to its lack of dust. It is easily colored. A limited amount of excelsior is woven into mattings and rugs.

C. Kinds of wood.

Basswood is best; balm of gilead, cottonwood and yellow poplar come next. Pine and spruce also are used. One cord of wood will yield 1,500 pounds of excelsior.

D. Process of preparation.

The wood is peeled, cut into 38-inch blocks, and the blocks split into slabs 5 inches to 6 inches thick. These slabs are thoroughly air seasoned under cover, and finally cut into two lengths of 18 inches each.

Frequently the core of blocks peeled on the rotary veneer machine is used for excelsior.

E. Machinery.

Excelsior machines are small, upright knife machines, or carry the knives on a disc set in rapid rotation. The modern machine, however, is an eight block horizontal machine consisting of:

I. Two sliding steel frames carrying eight tool heads into which the knives and the comb-like spurs are spanned. The sliding frames are moved by powerful cranks and pitmans on maple slides.

II. Two stationary frames, above the sliding frames, each having four sets of rolls, each set pressing a block by its rotation downward against the knives.

III. The shavings, falling through the sliding frame, are carried out by broad belts.

IV. The daily capacity of an eight block machine is 4,000 pounds of fine wood wool, or 10,000 pounds of mattress stock.

V. Additional machinery consists of automatic knife grinders, baling presses, cut off saws etc.

VI. The price of the machinery for a modern plant is about $2,000. About 30 horsepower are required.

§ XXXI. GROUND WOOD PULP AND CHEMICAL FIBRE AND THEIR MANUFACTURE.

A. Historical remarks.

Up to 1854 paper was made from cotton, linen and hemp fibre, precipitated from a mush in the shape of a matting.

Wood grinding was invented in 1854. Since 1867 the ground wood is refined by chemical processes which separate the wood into thinner strings of cells and free it from rosin, tannin, albumen, gums etc.

In the United States there were, in 1890, 82 mills producing $4,600,000 worth of wood paper, while the value of the output in 1900 approximated $20,000,000.

Rags, manila, straw and waste paper used as raw material for paper still outrank in value (in 1900) the wood used as raw material.

In 1900, close to 2,000,000 cords of wood were consumed, worth nearly $10,000,000; three-fourths being spruce and one-fourth poplar and miscellaneous.

If the United States shall conquer the Swedish and German export and supply the entire consumption of wood paper at home, 6,000,000 acres of well managed wood lands will be required to produce the raw material.

B. Statistical remarks.

One cord of wood yields one ton of ground pulp wood (mechanical fibre) or ½ ton of chemical fibre. In the so called "news grade" 80% of pulp is mixed with 20% of chemical fibre.

Japanese paper is made of the inner bark of a mulberry tree (Brussonetia).

For highest grades of writing paper, cotton and linen are used.

An average mill produces 25 tons a day.

A modern pulp plant requires annually, at least, 6,000 cords of wood; a modern fibre plant at least 25,000 cords.

The price of the product loco factory is about:

For ground wood pulp, $13 per cord;

For soda fibre, $20 per cord;

For sulphite fibre, $25 per cord.

C. The plant.

The plant requires an outlay of about $10,000 per ton of daily production. Unlike a saw mill, a paper mill cannot be shifted when the nearby supply of raw material is exhausted.

A plant must be located:

I. Close to water; water is not so much used for motive power as for the dissolution of the fibre in the washing process.

II. Close to cheap wood supply; wood must be plentiful and uniform, of a long, straight fibre, readily interlacing and white. Spruce is considered best, the price at river fronts being about $3.50 per cord and at mill from $4.50 to $5.50. Cottonwoods and poplar are next in importance. Price at river fronts $2. Hemlock and balsam are mixed with spruce in a daily growing proportion. Birch, beech and maple can be used only for wrapping paper and cardboard, the fibre being short, brittle and unbleachable.

The use of pine is handicapped by the expense of the removal of the rosin.

The Pacific spruces and cottonwoods may have a great future.

III. Close to cheap coal, since the coal consumption per pound of paper amounts to 5/16 of a pound of coal. So much coal is required for heating, drying and bleaching, that all excepting 15% of the machinery can be driven free of charge.

D. Process of manufacture.

The manufacture is either purely mechanical (ground wood pulp) or also chemical. In the latter case, distinguish between the soda process, the sulphite process and the sulphate process. The electric process, though very promising, is still in early infancy.

The principle of manufacture is:

Grinding and beating of wood in water until it forms a fluid pulp; allowing water to run off leaving a matted stratum of wet fibre; bleaching; drying; pressing.

I. Ground wood fibre.

(a) The wood is cut into bolts one foot long and five inches thick. The bark is removed, and the knots are usually bored out.

(b) The bolts are pressed against stone mill-wheels which turn slowly under constant influx of water. Bolts must be ground in the direction of the fibre.

(c) The fluid pulp is carried through sieves retaining the long splinters, which are transferred to a pulp engine for mechanical refining.

(d) The fibre is ground a second time both in stampers and rotary mills.

(e) The fluid is separated according to fineness by sieves of different mesh which allow the water to run off. The filtered mass is taken up by endless belts of cloth which carry it as a thin matting through a series of heated rolls.

(f) The mattings are dried by superheated steam, by pressure or in the air. Pulp is shipped in rolls about 3 feet long and 1½ feet in diameter. It is not paper but merely the leading raw material for ordinary paper.

II. Soda process.

This process consists of:

(a) Sawing wood into discs about 1 inch thick.

(b) Grinding and dissecting the discs into fragments about 1/24 inch by 1 inch in size.

(c) Packing the material into perforated iron boxes which are placed in digestors containing a solution of caustic soda.

(d) Boiling the wood for four hours under a pressure of 125 pounds.

(e) Grinding between stones.

(f) Repeated washing and sifting.

(g) Bleaching with chlorate of lime and washing.

(h) Taking up mass by endless rolls of cloth and drying it between heated rollers.

(i) Reclaiming caustic soda by boiling and melting.

III. Sulphite process.

Same as the soda process, excepting points "c," "d" and "g."

The wood fibre is first cooked without chemicals and then boiled for 60 hours with calcium sulphite—a cheap chemical usually prepared at the mill itself.

No or only little bleaching is required, the fibre being free from color when leaving the digestor.

The expense of manufacture per ton of sulphite fibre is said to be as follows:

Two tons of spruce	$ 9.00
Coal	3.00
Sulphur	3.30
Lime	.70
Labor inclusive of office force	7.00
Wear and tear	2.50
Total	$25.50

These figures may seem to be unusually high.

The sulphite process offers the following advantages:

(a) It is cheaper (no bleaching, cheap chemicals).

(b) It does not interfere with the strength of the fibre.

(c) It yields a larger output of fibre per cord.

Hence the sulphite process is rapidly superseding the soda process. Exception in poplar.

IV. Sulphate process.

It is adopted in mills originally arranged for caustic soda process. The chemical used is sodium sulphate, the price of which is only one-third that of caustic soda. It is reclaimed out of its watery solution by evaporating and melting. This process gives the old soda mills a new lease of life which were about to be forced to the wall by the superiority of the sulphite process.

V. Electric process.

The electric current is used to obtain from an 8% solution of common salt (Na Ci) its composing parts, viz., caustic soda and hydrochloric acid.

These substances, alternatingly acting upon the wood prepared in the manner described under II, a, b, and c, dissolve the lignin and destroy the incrustations of the fibre, so that pure cellulose remains in the digestors.

Two digestors are used, connected with the positive and the negative electrode of the current respectively.

The process is said to be faster and cheaper than the sulphite process. No bleaching required.

§ XXXII. TANNING MATERIALS AND TANNERIES.

A. Tanning materials.

Tanning materials used in the United States were in 1900:

Hemlock bark, 1,170,000 cords.
Oak, 445,000 cords.
Gambier, 128,000 bales.
Hemlock bark extract, 13,000 barrels.
Oak bark extract, 54,000 barrels.
Quebracho bark extract, 20,000 barrels.
Sumac bark extract, 8,500 barrels.
Chemicals, $2,225,000 worth.

In the sole leather, belt leather and harness leather industries, vegetable tanning material is still preferred. Mineral or chemical tannage, however, has been developed during the last ten years to a degree threatening to entirely supplant the old methods.

Since 1900, extracts obtained from chestnut wood have gained both favor and importance.

B. Tanbark in particular.

I. Notes on tanbark.

(a) The corky layers of bark do not contain any tannin and are usually shaved off. In Europe, young oak bark not having any cork is preferably used.

(b) Fresh bark contains on an average 45% water and shrinks heavily during the drying process.

(c) While oak bark must be peeled in spring immediately when the sap begins to rise (April-May), hemlock bark may be peeled at any time from May to September.

(d) Bark peeling season for oak is from early April to the end of June. Trees in the bottoms peel earlier than those higher up.

The bark on the uphill side of a tree is thinner than the bark on the downhill side.

Trees exposed to the weather, isolated, on unprotected slopes, have short boles but a heavier bark than those growing under the reverse conditions.

Dying trees will not peel.

II. Peeling process.

(a) Girdle the tree about four feet above the ground; remove bark from stump and roots; fell the tree in such a way as to leave the bole well raised above the ground.

(b) Notch (with axe) a line along the tree and rings around the tree every four feet. Have two men with "spuds" peel the ringed sections, and see that the pieces peeled are as wide as possible and, as near as possible, four feet long. Large pieces will dry well and will save expense in handling. Handling costs more than peeling.

(c) Lean the peeled pieces against the felled bole, preferably flesh side out, as high above ground as possible, and see that the air circulates freely around them.

(d) See that the bark is as little shaded as possible. Peel before leaves are out. Never leave bark to dry in a moist gully.

(e) Toward evening, turn the flesh side of the bark toward the object supporting it so as to protect it from dew. The expense of "curing" is so high, however, and the danger of spoliation by rain so great, that bark is now usually placed at once "bark side out."

(f) Pile the bark after two to three days, provided it is not wetted, close to the tree in loose piles. These piles are left for weeks in the woods. Bark is sure to mold if a rainy season sets in. Free access of air greatly reduces the danger of damage.

(g) Finally sled the bark, by hand sleds, cattle or mules, over rough trails (best grade is about 20%) to the wagon roads, to be removed to tannery or railroad.

III. Remarks.

(a) The minimum diameter of trees and branches peeled depends on the price of bark and the price of stumpage. At the present time, far from the tannery, it does not pay to peel pieces of less than 10 inches diameter.

(b) The expense of the harvest of oak bark is per cord:

Roads, 45c; felling, 27c; peeling, 57c; piling, 72c.

On the average a man will peel per hour from 0.3 to 0.38 cord.

(c) Tannin percentages of dressed bark are, after Sargent:

Mangrove	30 %	Burr and red oak	4.6%
Sumac	18 %	Chestnut	6.7%
Sassafras root	58 %	Douglas fir	13.8%
German oak	14 %	Eastern hemlock	13.1%
Cal. Chest. oak	16.5%	Western hemlock	15.1%
Live oak	10.5%	Eastern spruce	7.2%
Chestnut oak	6.2%	German spruce	8 %
Spanish oak	8.6%	German fir	6 %
Black oak	5.9%	Larch	7 %
White oak	6 %	Birch	4 %

C. Wood extracts in particular.

I. Tannin extracts are manufactured from bark, chestnut wood, quebracho, mangrove and oak. Quebracho wood contains 24% of tannin; chestnut wood 14% (?) of tannin.

II. The wood is shredded in a chipper and the tannin extracted (not entirely) by steam or hot water under pressure. The liquid obtained is condensed.

III. While in France the sappy branches and young shoots of chestnut are preferred, in America the heart wood and especially the butt is preferred.

IV. The wood is cut 4 feet to 5 feet long. The leather trust uses a cord of 160 cubic feet = 1¼ cords of 128 cubic feet.

V. Clear water, cheap transportation and cheap fuel are required for successful manufacture.

Only sound wood is used; wormholes in chestnut, however, do not interfere with its value.

VI. Extracts exposed to air or exposed to heat spoil rapidly.

VII. Extracts are shipped in barrels of 56 gallons capacity or in tank cars.

VIII. The price of chestnut extract is 1½c to 2c per pound. At a price of 1½c, extract is cheaper than oak bark at $6 per cord.

IX. One cord of chestnut wood yields 500 pounds of extract containing about 25% tannin.

D. The methods of tannage employed nowadays are:

I. Tanning by means of aluminum salts.

II. Chamoying by means of certain oils or acids of oils.

III. Tanning by salts of chromium.

IV. Vegetable tanning, using the wood of quebracho, chestnut and oak; the bark of various oaks, hemlock, spruce, douglas fir, birch, larch, willows; fruits, cups and galls, i. e., divi-divi, catechu, myrobalans; further, the leaves of sumac. Instead of using these vegetable matters, their watery extracts frequently are applied.

E. Object of tanning.

Tannage tends to render the skin permanently supple and durable by impregnation with tannin. Aside of the mechanical imbedding of molecules by impregnation, a chemical action (fermentation) may take place in the case of bark tannage, due to the presence of microbes in the bark, chemically binding the tannin to the albumen and gelatine of the skin.

F. Criteria of a good method of manufacture are:

I. The weight of the leather produced. Since leather is sold by the pound, the tanner tries to press into the hide the maximum amount of tannin, tannin being much cheaper than hides.

Beyond a certain point, this extravagance of impregnation fails to increase the wearing qualities of leather and is therefore useless to the buyer.

II. The color of the leather produced and the adaptability of the leather for coloring.

III. The possibility of tannin being washed out through wear and tear. From chromium tanned leather even a boiling process will not remove the tannin.

IV. Quickness in filling orders and amount of capital required.

V. Cheapness of manufacture. The best leather is produced slowly only by use of materials rather poor in tannin.

G. Statistical notes.

I. One ton (2,240 pounds) of hemlock bark will tan 300 pounds of sole leather or 400 pounds of upper leather; 4 to 5 pounds of good oak bark are required to produce 1 pound of sole leather.

One acre of hemlock wood is said to yield about 7 cords of bark, and 1,500 board feet of timber are said to carry one cord of bark.

One acre of hardwoods will yield on the average not over one-half cord of chestnut oak bark.

One cord of chestnut wood yields one barrel of extract.

II. The price of bark at the tanneries ranges from $4 to $16 per cord. The cord of bark is not measured, but is weighed, 2,240 pounds being called a cord.

The price of a cord of chestnut wood f. o. b. cars is $2.50 to $3.

III. One hundred pounds of dry hides yield 150 to 185 pounds of leather; 100 pounds of green hides yield 60 to 80 pounds. The cost of the hide amounts to from 50% to 75% of the cost of production.

IV. The number of tanneries in the United States has greatly decreased from the year 1880 (5,628 plants) to 1900 (1,306 plants). The small tanneries using old fashioned and wasteful methods have been killed by the large and intelligently conducted modern plants. The leather trust controls over 100 of the largest plants.

The investment of capital has increased from $73,000,000 in 1880 to $174,000,000 in 1900.

The cost of raw material, $155,000,000, and the value of the product, $204,000,000, have remained almost unaltered during the same period.

V. "Hides" are obtained from oxen, cows and horses; "kips" from yearling cattle; "skins" from calves, sheep, goats and pigs.

Calf skin is used for upper leathers of shoes; sheep skin for cheap shoes, linings and gloves; goat skin for fine upper leathers and gloves.

Hides often are split and the so called grain and flesh splits are used in place of goat and calf skin.

H. Manufacture.

The old fashioned methods used from time immemorial consisted of rinsing skins; scraping off the flesh; treating the hair with lime; placing alternating layers of crushed oak bark and of skins in rough vats. The time consumed in this process of manufacture frequently exceeded a year. The best leather, however, is produced in this way.

The modern process in manufacturing sole, belt and harness leather is:

I. Soak in soft water (heated to less than 70° F.) to remove salt and blood and to restore the original softness and pliability of the skin.

II. Loosen hair by either liming green hide in milk of lime for three to six days or sweating dry hides at 70° in a close room, inviting a partial decomposition of the hair sheath. The sweating is preferred for acid hemlock tannage.

III. Remove on the "beam," by hand or machine, flesh, hair, blood, lime, dirt.

IV. Prepare the liquors in the leech house The liquors contain often from 5% to 6½% of tannin only. Cold water extracts only part of the tannin from either bark or wood. Very hot water may extract all, extracting with it, however, undesirable coloring matters and killing the fermenting microbes.

V. The tannage itself is either "Acid hemlock tannage" or "Non-acid hemlock, oak and union tannage."

(a) Acid hemlock tannage consists of:
1. Coloring in a dilute solution of tannin.
2. Placing skin for 2 to 4 days in a sulphuric bath (of 10% to 30%) by which the hide is swelled to a great thickness.
3. Placing the hide in a strong, concentrated solution of tannin.

(b) Non-acid hemlock, oak and union tannage (2-3 hemlock, 1-3 oak bark):
1. Treat the hide, to begin with, with very weak solutions of tannin.
2. Gradually increase thereafter the concentration of the liquors. If a hide is at once hung in a strong liquor, its outer layers only are tanned. The hide will not swell, and the inner layers will fail to be impregnated.

VI. The operations finishing the process of manufacture are: Washing; scouring off the so called bloom; stuffing (which means bathing in grease); drying; dampening and rolling under pressure; redrying; glossing on a brass bed by brass rollers.

§ XXXIII. CHARCOAL BURNING IN CHARCOAL KILNS.

A. Distillation of wood.

Destructive distillation of wood, under reduced admission of air, yields chemically the following proportion of substances:

I. 25 % of non-condensable gases, viz.:

carbon monoxide	acetylene
carbon dioxide	propene
marshgas	ethylene

II. 40% of condensable vapors, viz.:

acetone	formic acid
furfurol	butyric acid
methyl alcohol	crotonic acid
methylamine	capronic acid
acetic acid	propionic acid

III. 10% of tarry liquid, viz.:

tar	cresol
creosote	phlorol
toluol	naphtalene
xylol	pyrene
cumol	chrysene
methol	paraffin

IV. 25% of solid residue, viz.:

charcoal	inorganic salts

B. The kiln process.

In the kiln process of destructive distillation of wood, all of the above substances are allowed to escape unused, excepting the solid residue.

Modern technology succeeds in catching and utilizing several of the substances given under II and III, as appears from Section XXXV.

Still, the large majority of the charcoal commercially used is produced by the old and wasteful charcoal kiln.

C. Characteristic qualities of charcoal.

I. Charcoal has per cubic foot a larger heating power than wood.

II. Owing to its lesser weight, it is very cheaply transported.

III. Its freedom from sulphur and phosphates makes it valuable for metallurgic work (Swedish charcoal iron).

D. The work at the kiln.

I. For use in kilns, wood must be thoroughly seasoned, free from heavy knots. The billets must have equal length.

The kilns should be charged with one species and one assortment of wood only at a time.

II. The work consists of:

(a) Preparation of ground near water by leveling and hoeing the soil, by removing roots and stones, by raising the center of the circle to be occupied by the kiln about 10 inches over its circumference.

The diameter of the circle is from 15 feet to 30 feet usually. The best soil is loamy sand, which secures proper regulation of the draft.

The site should be protected from wind. Twigs are woven into a wind screen on the windward side, if necessary.

(b) Erecting the "chimney" by placing three or four poles of even height at one foot distance from a center pole, fastening them together to the central pole by withes.

The chimney is cylindrical if kiln is lighted from above, pyramidal if kiln is lighted from below.

The chimney is filled with inflammable substances (dried twigs etc.).

(c) Constructing the kiln proper.

The kiln should have a parabolic form. It consists of two or more tiers of billets placed almost vertically, the bark turned outward, the big end downward, the finest pieces near the chimney and near the circumference, the largest pieces half way between.

These tiers are topped by a cap, consisting of smaller billets placed almost horizontally. A cylindrical chimney extends through the cap. A pyramidal chimney is closed by the cap.

In the latter case a lighting channel is left on the ground running radially on the leeward side from the bases of the pyramidal chimney to the circumference. This channel, too, like the chimney, is filled with easily inflammable material.

(d) Stuffing all irregularities, interstices, cracks etc. showing on the outside of the kiln with small kindling.

(e) Covering the kiln by two draft-proof layers so as to exclude or restrict the admission of air.

1. The green layer, ½ to ¾ feet thick, made of green branches, grass, weeds and moss.
2. The earth layer, 4 inches to 6 inches thick, consisting of wet loam, charcoal dust etc.

   If kiln is lighted from below, a belt about 1 foot high running around the circumference on the ground is left without earth cover until fire is well started.

   The earth layer and the green layer are thoroughly joined by beating with a paddle.

   In large kilns a wooden frame (the armor) consisting of T sections is used to prevent the cover from sliding down.

III. The kiln is lighted early in the morning on a quiet day. The cylindrical chimney is stuffed up with wood from above and then closed on top by heavy covering after the fire is well started in the cap.

The lighting channel, in the case of a pyramidal chimney, is similarly stuffed and closed.

IV. The regulation of the fire and of the draft are the most important functions of the attendant who guides the fire evenly and gradually from the cap down to the bottom.

The means of guidance are:

(a) To check draft, increased earth cover.

(b) To increase draft, holes of about 1½ inches diameter punctured through the cover with the paddle reversed.

If wind is strong, all holes are closed and earth cover increased.

Cracks forming in the cover must be closed at once.

In dry weather the kiln is continuously sprinkled.

The kiln may explode if cover is too heavy and draft too strong.

The color of the smoke escaping through the punctures indicates the completion of the charring process above the holes (transparent bluish color).

The holes are then closed, and another row of punctures is made about two feet below the closed holes.

V. Refilling is required where dells are forming irregularly, while the kiln gradually collapses to half of its original volume.

For refilling, the cover over the dell is quickly removed, all holes having been closed beforehand, and the dell is rapidly filled with fresh wood.

VI. When the bottom holes show the proper color of smoke, the charring process is completed. All holes are then closed and the kiln is allowed to cool.

The duration of the charring process is from six days to four weeks, according to size of kiln. The contents vary between four and sixty cords.

VII. The kiln is gradually, beginning at the leeward side, uncovered, and the crust of earth, after hoeing, is thrown on again. The earth, trickling down, quenches the fire. After another twelve to twenty-four hours, preferably at night, the coal is taken out in patches.

Water must be ready at hand, since fire usually breaks out when coal is drawn.

E. Statistical notes.

The loss of weight in the charring process is 75 %.

The loss of volume is 50 %.

In America charcoal is sold by the bushel, a bushel weighing about 25 lbs.

F. Appendix.

In Norway, Sweden and Russia kilns of trapezium form are built of peeled logs 15 to 30 feet long.

The lighting channel runs lengthwise on the ground.

The kiln is lighted at the narrow end and covered with green branches and earth in the usual manner.

The side walls being almost perpendicular, the cover is held in place by slabs spliced against the walls. No refilling is required.

Fire is conducted from the top of the kiln at the big end toward the bottom of the kiln at the little end.

The process lasts six to eight weeks.

The billets are placed horizontally, skidway fashion, the largest billets being put in the center and the smallest at the head and at the foot of the kiln.

§ XXXIV. LAMPBLACK AND BREWER'S PITCH, AND THEIR MANUFACTURE.

The former is used in the manufacture of patent leather; the latter for pitching beer barrels.

A. Raw material is spruce rosin.

B. The process consists in a combined melting and pressing of rosin. The brewer's pitch runs out through a pipe connecting the bases of the melting vats with a cooling vat.

C. The solid residue remaining in the vats is slowly burned in an oven. The smoke passes through a cool room and into a smoke room, the top opening of which is covered by a common bag. In this room pine soot or lampblack is deposited. The draft is regulated by the attendant according to the shape or bulge which the bag assumes under the influence of the smoke.

D. Some turpentine can be derived at the same time if the vats are closed air tight and if the escaping gases are condensed in a worm.

§ XXXV. PYROLIGNEOUS ACID, WOOD (METHYL) ALCOHOL, AND THEIR MANUFACTURE.

A. Raw materials: These are, preferably, broad leafed species—beech, birch, maple—which must be thoroughly seasoned.

Heavy stuff is preferable, it is said, to small stuff.

B. Distillation: The process consists in a dry distillation of the wood, differing from the charcoal kiln process merely by allowing the gases to condense.

The distillation takes place in large horizontal iron cylinders, usually about 10 feet long by 5 feet in diameter, into which the wood is run on steel trucks. After closing the cap of the cylinders (admission of air reduces the output of pyroligneous acid) the cylinders are slowly heated to a redhot. The gases forming are led through long worm pipes into a condenser.

Not all of the gases formed allow of condensation. The uncondensable gases are conducted to the fire room.

At the bottom of the cylinder, tar is forming and is let out by a system of pipes into a collecting basin. Conifers yield more wood tar than hardwoods.

C. Further treatment.

The gases, condensed to a liquid a large proportion of which is water, are then treated with lime. Lime neutralizes the pyroligneous acid, forming acetate of lime.

The liquid is then redistilled, wood alcohol going over first, water next. The residue is boiled down in open pans to the consistency of a sugar, the acetate of lime of commerce. From it acetic acid and its salts are derived in chemical works.

D. The output.

One hundred volumes of air dry wood furnish up to forty-eight volumes of pyroligneous acid.

One and three-quarters cords of beech yield 2,650 pounds of liquids, 25 gallons of tar and 700 pounds of charcoal.

The 2,650 pounds of liquids furnish 200 pounds of acetate of lime and 9 gallons of 82% wood alcohol.

E. Use: Acetate of lime is used by the chemical industry in the manufacture of acetic acid and of the salts of acetic acid.

Wood alcohol is used largely in the manufacture of varnishes, dyes, celluloid and especially for heating. It is poisonous.

§ XXXVI. TRUE OR AETHYL ALCOHOL AND ITS MANUFACTURE.

A. Principle underlying the process.

Wood boiled under pressure in the presence of acids yields sugar (dextrose). This sugar, freed from the acid admixed, is allowed to ferment under the influence of yeast and changed into aethyl alcohol.

B. Raw material:

Cottonwoods, linden, yellow poplar are said to be superior to the heavy hardwoods as well as to conifers. Possibly chestnut wood, from which the tannin is withdrawn in tannin extract factories, may answer as a raw material. Unless sawdust is available, the wood is prepared, sawed and pounded as if it were to be used in the manufacture of chemical fibre.

C. Process:

The acid used does not enter into any chemical combination with the wood. It merely acts by its presence and is said to be most efficient when in statu nascendi. Sulphuric acid, sulphurous acid, hydrochloric acid or a mixture of these and similar acids are used.

The temperature of the lead-coated vats containing acid and wood is gradually raised to about 250° F. Hydraulic pressure is also applied, either before or after the boiling process. As a matter of fact, the partial conversion of cellulose into starch seems to be due to pressure—not to boiling. The acid is then neutralized and the temperature reduced to about 85° F. By the addition of yeast (fed on phosphates of potash and of ammonia) a violent fermentation of the sugar is started, ending within thirty-six hours, when the yeast has dropped down to the bottom of the vat while the sugar has been converted into alcohol.

The liquid is distilled and redistilled, yielding alcohol of any desired concentration.

The wood remaining—only 20% of its weight seems convertible into sugar—might be used for paper manufacture or as fuel for the boilers. Classen claims, after his methods, to obtain at least 30% dextrose from absolutely dry wood.

D. Output.

One hundred pounds of dry wood are said to actually yield about 5 pounds of 96% alcohol. The process of manufacture is far from being perfect. A number of chemists, notably Classen, are hard at work to further improve and to cheapen the process. Cheap alcohol—a fuel, a source of light and a source of technical energy—manufactured from wood will be a boon for household, industries and forest.

§ XXXVII. ARTIFICIAL SILK MADE FROM CELLULOSE.

A. History.

Artificial silk was first prepared by Hilaire de Chardonet in 1884. Today many patents and numerous factories to exploit them exist in the old country.

B. Process.

There are two main processes in use, namely:

I. A solution of nitrocellulose, a compound of nitric acid and cellulose in ether or alcohol, is pressed through minute capillary pipes, appearing in long, silky threads. Additional chemicals (methods of Vivier, Lehner) reduce or entirely destroy the inflammability of the product.

II. Pure cellulose is readily dissolved in a few chemicals only, notably in concentrated copper oxide dissolved in ammonia. This solution forms a waxy mass which is pressed through minute capillary openings and appears in the form of supple, long, silky threads, immediately entering a bath of sulphuric acid. Here cellulose is set free, now a solid thread, while blue vitriol and sulphate of ammonia result at the same time. The threads are spun exactly like threads of natural silk.

C. Qualities of product.

Artificial silk has an exquisite shine and is easily colored before the pressing process. The tearing strength of silk obtained from nitrocellulose, however, is now only 33% of that of true silk, its toughness only 45%.

Artificial silk is used on a daily increasing scale in silk weavings. New methods and modifications of manufacture continuously increase its chances as a substitute for natural silk.

§ XXXVIII. MANUFACTURE OF OXALIC ACID FROM WOOD.

A. Principle.

Any wood heated to about 400° F. in the presence of caustic substances yields, among many other products of disintegration, a goodly percentage of oxalic acid.

B. Raw material.

Any wood finely ground or pulverized, and especially sawdust and mill refuse, is well adapted to the process—oak as well as beech, pine, chestnut etc. Cottonwood is said to be rather poor as a raw material.

C. Process.

A mixture of caustic soda, caustic potash and sawdust is heated, under continuous stirring, in open pans (½ foot deep and 6 feet square) by superheated steam or air. The temperature is gradually raised to 480° (not over) F., remaining at that figure for about 1½ hours. The melted mass, consisting of oxalate of sodium and of carbonate of potassium, is thrown into water and allowed to cool, when the oxalate forms a dough of minute crystals. This dough is freed from water by centrifugal power, then treated with lime and thereafter with sulphuric acid, with the result that gypsum is precipitated from a solution of oxalic acid.

D. Output.

One hundred parts of wood yield up to 80 parts of oxalic acid.

The quantity of output depends on proper mixture of caustic soda and potash, and on proper regulation of the temperature.

§ XXXIX. THE MAPLE SUGAR INDUSTRY.

In the sap of all broad leafed species considerable quantities of sugar are found. This quality is commercially important, however, only in the case of hard maple. In 1900 there were produced 51,000,000 pounds of maple sugar and about 3,000,000 gallons of maple syrup.

New York, Vermont and New Hampshire lead this industry. Seventeen percent of all granulated sugar made in the United States is obtained from the maple tree.

Vermont protects its maple sugar industry from counterfeits by State inspection and official stamp.

A. Tapping the trees.

I. Time. End of January and February is best.
Cold nights and hot days necessary for best results.

II. A hole is made, with an auger, ½ inch to ¾ inch in diameter, slightly slanting towards the entrance, to a depth of 2 inches to 8 inches, at a point 2 to 3 feet above ground. Holes on north side of tree said to be most productive. Holes 10 feet above ground do not yield any sap.

III. A wooden or galvanized iron spout (3 to 8 inches long with a hook at the end to suspend the bucket) is inserted into the hole.

IV. Buckets are emptied at least daily, as the sap ferments easily. The sap, poured into large tanks resting on sleds, is quickly taken to the sugar shed. Buckets must carefully be kept clean.

V. Production per tree is 4 lbs. of sugar per season. The season lasts not over a month. The trees are not affected by tapping, either in quality or vitality. A new hole is made every year.

B. Boiling process.

Immediately after gathering, the sap is boiled down in open pans.

I. Manufacture of sugar.

Syrup is boiled to the consistency of wax, poured into forms and stirred to prevent formation of large crystals. Crystalization takes about 12 hours. Fifty quarts of sap yield 2 lbs. of sugar.

II. Manufacture of syrup.

The sap is boiled down to a lesser consistency and at once canned or bottled.

§ XL. NAVAL STORES, THEIR PRODUCTION AND MANUFACTURE.

A. Statistics.

In 1902 the United States produced 600,000 bbls. of turpentine worth $13,200,000; 2,100,000 bbls. of rosin or colophany worth $4,200,000.

One acre of orchard yields in three years' tapping 25 gallons of spirits of turpentine, worth $8, and 800 pounds of rosin worth $4, at a labor expense and manufacturing expense of $10. Thus a profit of $2 per acre is left to the owner.

Orchards are leased actually at $1 to $2 per acre for three years.

B. Methods of orcharding.

I. Southern method (also Austrian method).

(a) Species used: Longleaf pine (used now down to 8 inches in diameter); Cuban pine; echinata (small trees preferred); after W. W. Ashe, also Taeda; in Austria, Pinus Austriaca.

(b) Operations of the first season:

1. Boxing: The tree is cut into, 8 inches above ground, with a narrow, thin-bladed "boxing axe." Usually two boxes to a tree, on opposite sides. Width of box is 14 inches; depth horizontally 4 inches, vertically 7 inches; height of the tip above the lip about 10 inches. Boxing takes place in January and February.

2. Cornering: Immediately after boxing the tree is "cornered." Cornering implies the removal of two triangular strips of bark and sapwood above the

box, running as high as the tip. The resulting grooves act as gutters for the rosin.

3. Hacking: Hacking or chipping begins in early March and is continued until October. The "hack" is a bent-bladed, sharp instrument which is used obliquely across the tree, producing a series of V shaped grooves in the outer layers of sapwood above the box and the corners. The points of the Vs stand in a vertical line over the tip. The surface thus scarified is called a face. The chipping removes ½ inch of sapwood. The face of the first season is from 18 inches to 24 inches high and always remains as wide as the box.

4. Collecting: The virgin dip accumulating in the box during the first season is dipped out seven or eight times; the rosin, hardened on the face, is scraped off.

(c) Operations of subsequent seasons:

In the following seasons, the face is gradually carried upward until the working becomes unprofitable.

The output of dip, now called yellow dip, decreases from year to year, with the increase of distance between freshly hacked face and box. The scrape preponderates over the dip.

Longleaf pine may be tapped for an indefinite number of years, if intermissions of a few years permit the trees to recuperate.

II. French method (Hugues system).

(a) Species used: Pinus maritima, which grows on the sand dunes fringing the western shore of France, is exclusively treated to this method.

(b) Operations:

1. Remove the rough bark around the tree to prevent pieces of bark from falling onto the face.

2. In early March make a scar close to the ground 4 inches wide and 1¼ feet high, removing 2/5 inch of sapwood. The instrument used is a bent-bladed, crooked-handled axe.

3. Insert a toothed collar, made of zinc or

iron, into an incision cut with a sharp curved knife at the bottom of the scar.

4. Hang a glazed earthen pot on a nail immediately under the lip of the collar. The pot is 5½ inches deep, 5½ inches wide at top and 3 inches wide at bottom.
5. Extend the 4-inch scar week by week upward until October, taking each time a thin layer of sapwood off the old face. The final length of the face reached in a number of years is up to 30 feet.
6. The collar and cup are moved each spring to the top of the preceding year's face.

The nailhole in the pot allows rainwater to run off, since water is lighter than crude rosin.

The pot is often covered with a wooden lid, the face itself by rough boards.

III. Dr. Charles H. Herty's gutter method.

(a) Applicability:

The method can be applied to bled or unbled trees. It has been tried by the Bureau since 1902 in the Southern pineries.

(b) Operations of the first season:

1. Use cornering axe to provide two flat faces 8 inches above the ground forming an angle of about 120°; each is half as high as long; total width about 14 inches. Two men, right and left handed, cut 3,000 faces per day.
2. Make incisions at base of faces, one at least an inch higher than the other. Tool used is a broad axe having a 12-inch straight blade.
3. Insert galvanized sheet iron gutters into the incisions. Gutters are 2 inches wide and 6 inches to 12 inches long, bent to proper form (angle 120°) by a tilting-bench contrivance. The lower gutter projects by 1½ inch over the mouth of the upper, the projection forming a spout.
4. Fasten an earthen cup of a capacity equaling that of a box (5½ in. x 3½ in. x 7 in.) on the side of the upper gutter in such a way that its rim stands ½ inch below the spout, and that the nailhole is as far as possible from the spout. The

nailhole should be two inches below the rim of the cup.

5. Chipping as in method I; cups emptied from time to time into collecting buckets.

(c) Operations of subsequent seasons:

Next season, the uppermost chipped channels are used for the insertion of the gutters. The cup is fastened at the upper end of the face made in the previous year.

(d) Equipment:

Equipment required for 10,000 boxes is: 10,500 cups (cost 1¼c each = \$131.25); gutter strips made from 1,886 pounds of galvanized iron, 29 gauge (cost of material \$103.27; cutting and shaping gutters cost \$4); 10,000 six-penny nails (costing \$1.05); freight charges are about \$30; labor at the trees requires an outlay of \$80.

(e) Results:

Dr. Herty justly claims financial superiority of this method over the old Southern method, due to an increased output of turpentine.

C. Manufacture of naval stores from pine products.

I. From rosin of longleaf pine etc.

(a) Melting crude rosin in order to separate from the liquid constituents pieces of bark, wood and a pitchy residue.

(b) Dry distillation of the latter in a copper distilling apparatus, heated usually from an open fire beneath the apparatus; but preferably from steam of high temperature.

(c) Cooling of gases in a worm and condenser where there are obtained:

1. An upper layer of turpentine which is redistilled.
2. A middle layer of rosin (colophany) of a light yellow color, which is sifted repeatedly into different qualities.
3. Water forming the lowest layer.

II. From roots, branches and stumps of pine, the stumps to be dug out a few years after the trees are cut.

(a) Cut the wood into kindling.

(b) Fill it (from above) into a gasproof brick stillroom, 15 feet high and 6 feet through, holding from 5 to 6 cords of kindling. The top and bottom of the still are funnel shaped and provided with pipes. The still is surrounded by the fire room.

(c) After closing the upper funnel, apply heat very gradually. Within 24 hours turpentine begins to escape through the top pipe which leads through a worm into a condenser. When the gases appear dense and thick, the top pipe is closed and the gases (now largely containing pyroligneous acid) are forced through the bottom pipe to be condensed in another condenser. Light (at a later stage dark) tar is let out through this same pipe. The fires are checked when the tar begins to flow freely.

(d) The process takes, for heating, 3 days; for cooling, 8 days. Charcoal is left in the still room. Proper regulation of temperature is most essential.

(e) One cord of pine kindling yields about 25 gallons of tar, 1 to 1½ gallons of machine oil, ½ to 1 gallon of turpentine, some pyroligneous acid and ½ cord of charcoal.

III. Uses of naval stores:

(a) Spirits of turpentine are used for colors, paints, varnishes, asphalt laying, solvent for rubber.

(b) Colophany is used for glue in paper manufacture, varnishes, soap making, soldering, manufacture of sealing wax.

(c) Wood tar made of conifers is lighter than water (owing to spirits of turpentine therein contained); made of broadleafed is heavier than water. It contains tolnol, xylol, cumol, naphtalin, paraffin, phenol, kreosol, pyrogalol and many other carbohydrates.

Caustic soda causes the solution of the aromatic alcohols contained in wood tar. From this solution true creosote is derived.

Dry distillation of wood tar yields:

1. Light wood oil;
2. Heavy wood oil;
3. Shoemaker's pitch, a residue.

D. Conifers other than pines are used only to a limited degree in the manufacture of naval stores.

(a) The larch yields the so-called venetian turpentine, which is obtained by boring (with 1½ inch auger) a deep hole into the heart of the tree. The hole is closed by a plug. After a year the turpentine, entirely filling the hole, is extracted.

(b) Spruce was tapped for turpentine on a large scale in the old country before the orchards of the South were developed. Only scrape is obtained from long and narrow faces. The scar invites red rot, badly checking the value of the timber. The output in ten years is, per acre, 73 lbs. of crude spruce rosin.

(c) Fir has rosin ducts only in the bark. Blisters or bubbles of the bark filled with rosin yield the so-called "Canada balsam" and "Strassburg turpentine," collected in tin cans. The blisters are opened with the rim of the can.

§ XLI. VANILLIN.

Vanillin, a substitute for vanilla, which has caused the price of bean vanilla to decline rapidly and permanently, is obtained from spruce (fresh cut) by removing the bark and collecting the sap either with sponges or broad-bladed knives. The sap is then boiled, strained and condensed in the vacuum pan to one-fifth of its former volume.

In the cooling room, crystals of coniferine are formed from the syrup. Coniferine, when treated with potassium bichromate and sulphuric acid, is oxydized into vanillin. The syrup obtained as a by-product is distilled and used in the manufacture of alcoholic beverages.

Eighty gallons of sap yield one gallon of coniferine.

§ XLII. BEECHNUT OIL.

Mast years of beech occur, according to climate, every 3 to 8 years. The nuts are gradually dried, slightly roasted, peeled and cleaned of shells; then either ground, applying moderate heat, or pounded in mills by stampers. The oil oozing out is strained and placed in a cool room (in earthenware vessels), where the clean oil forms a top layer to be poured off gradually.

The residue is pressed into cakes and used as feed for stock.

Two hundred pounds of dry beechnuts yield 5 quarts of oil.

§ XLIII. PINE LEAF HAIR.

Pine leaf hair, or curled pine straw, is used as a substitute for wool and cotton in upholstering, carpets etc. The stuff is mothproof.

Three hundred to 400 pounds of needles yield 100 pounds of wool.

The price is $3 to $12 a cwt., according to the quality.

A by-product is known as pine needle extract, used by the perfumer.

The process of manufacture consists of:

Drying the freshly cut needles; steaming; fermentation; crushing and disfibreing in pounding mills; repeated washing of the feltlike mass; loosening on sets of oscillating sieves; drying and bleaching. The product has a greenish or yellowish color. It is called "pine hair" in North Carolina, where the industry, now extinct, promised a successful career twenty years ago.

§ XLIV. IMPREGNATION OF WOOD.

Impregnation tends to increase the durability of wood by injecting an antiseptic liquid and may mean a desirable or undesirable change of color, and in some cases fireproofing. Little is known about the latter.

Four principles may be applied:

A. Immersion:

I. The oldest method used was immersion in a strong solution of salt. European railroads place ties for eight days in large tanks filled with a light solution of corrosive sublimate. No other work required. The method is called "Kyanizing." Drawbacks are that the liquid is washed out on wet ground; that spikes do not hold well in the timber. Expense per cubic foot, 6½c.

II. "Metalized" wood is obtained as follows:

Immerse the wood in a solution of sulphate of iron; then smear the wood with chloride of calcium. In the outer layers of the wood gypsum (sulphate of lime) is formed together with chloride of iron. Such wood is impermeable to water and has a metallic shine.

B. Boiling:

I. Boiling in salt water or in a solution of borax seems to be a method rarely practiced. Boiling, however, with exhaust steam, when a black juice is forced out of the log, is frequently seen abroad.

In the latter case the log is practically steam dried.

II. "Franks" mixture consists of 95 % liquid manure and 5 % of lime. It is pumped into large vats, within which the wood is boiled for 3 to 8 days. The liquid enters to a depth of about 3 inches and darkens the wood to a mahogany tint.

III. A method called "siderizing" injects by a boiling process a solution of copperas. The wood is then dried, and liquid glass (a hot solution of silicate of aluminum) smeared on the surface. By a chemical reaction silicates of iron are formed in the outer layers, which are insoluble in water and resist decomposition. The wood at the same time obtains a beautiful gloss.

C. Use of hydrostatic pressure:

A solution of sulphate of copper (blue vitriol) is used after Boucherie. It is kept in a tank 30 ft. to 40 ft. above ground. The timber must be fresh cut with the bark on and is spread on a rough log-deck. At the big end of each stick a ring made of rope is held in place by a board or heading nailed to the log. A hose connected with the tank injects the liquid into the small cleft formed between log and heading. After a few hours, drops of vitriol appear at the small end, showing that the process is complete. The pressure being slight, only the outer sappy layers are impregnated. This method is largely used abroad, often in the woods themselves, for telegraph poles of pine, spruce, fir etc. Expense per cubic foot, 4c.

D. Use of steam pressure:

The wood is dried thoroughly, then placed on small steel cars running into long cylinders or boilers, closed by a strong head. A vacuum pump removes the sap water and causes a vacuum to form in the wood itself. Then an antiseptic liquid is pressed into the boilers; temperature of liquid is 150° to 200°.

The liquids used are:

(a) Chloride of zinc.

(b) Creosote or rather cheap coal tar oils.

(c) Gases of tar oils (so called thermo-carbolization).

The creosoting method is used for ties and paving blocks. Creosoted timber holds nails well; creosote is not washed out by rain; on the other hand, the darkened color of the wood is sometimes objectionable. It is claimed that creosoting in the United States has failed, probably because an extravagant amount of the liquid has been pressed into the timber. In Germany the expense per tie is only 63c as against $1.25 in the United States.

E. Results:

Heart wood is not as permeable and hence not as impregnable as sap wood. Maple, birch, beech, spruce, sappy pine etc. are more benefited by impregnation than white oak, longleaf pine etc. Generally the duration of life of impregnated ties is increased at the following ratio: Beech, 400%; yellow pine and oak, 200%; spruce, 50%.

Obviously, every additional pound of preservative pressed into the fibre has a lesser effect on the lastingness of the wood than the preceding pound. For every woody species the limit must be found at which additional impregnation proves unremunerative.

FOREST MENSURATION

By

C. A. SCHENCK, Ph.D.

Director Biltmore Forest School, and Forester to the Biltmore Estate

MCMV

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LECTURES ON FOREST MENSURATION

SYNOPSIS OF CONTENTS BY PARAGRAPHS.

SECTION III.—VOLUME OF FORESTS.

CHAPTER II.—AGE OF TREES AND OF FORESTS.

CHAPTER III.—INCREMENT OF TREES AND OF FORESTS.

SECTION I.—INCREMENT OF A TREE.

SECTION II.—INCREMENT OF A WOOD.

CHAPTER IV.—LUMBER.

CHAPTER V.—STUMPAGE-VALUES.

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11

FOREST MENSURATION

PARAGRAPH I.

DEFINITION AND SUBDIVISION.

Definition: By "Forest Mensuration," the forester ascertains the volume, the age, the increment and the stumpage value of trees, parts of trees and aggregates of trees. As a branch of forestry, forest mensuration may be divided into the following five parts:

I. Determination of volume of trees cut down, of standing trees and of forests.
II. Determination of age of trees and of forests.
III. Determination of increment of trees and of forests.
IV. Determination of sawn lumber.
V. Determination of stumpage value.

Circular 445 of the Bureau of Forestry defines mensuration as "the determination of the present and future product of the forest."

American literature is found in Bulletin 20, Division of Forestry; Bulletin 36, Bureau of Forestry; S. B. Green, page 132; Lumber & Log Book and Lumberman's Handbook, edited by the "American Lumberman."

CHAPTER I.—VOLUME.

SECTION I.—VOLUME OF TREES CUT DOWN.

PARAGRAPH II.

UNITS OF VOLUME.

The volume of a tree or of a tree section is expressed:

1. For scientific purposes, on the basis of exact measurements, in cubic feet or cubic meters.
2. For practical purposes, by estimates according to local usage, often assisted by partial measurement, in local units (feet board measure; standards; cords; cubic feet; cord feet; etc.).

PARAGRAPH III.

MATHEMATICAL FORM OF TREES.

Trees do not grow, like crystals, according to purely mathematical laws. Tree growth is deeply influenced by individuality, by surroundings, by accidental occurrences, etc.

The body of a tree, considered as a conoid (a solid body formed by the revolution of a curve about an axis), is very complicated, being formed by a curve of high power. This is the case even in straight and clear boled conifers. The tree bole shows, however, in certain sections of its body frequently a close resemblance to a truncated neilloid, cylinder, paraboloid and cone.

The longitudinal section of conoids is outlined by a curve corresponding with the general equation

$$y^2 = px^n$$

in which y is the ordinate (corresponding with the radius of the basal area), x the abscissa (representing the height of the conoid), n the power of the curve; whilst p is merely a constant factor. The volume v of the conoid is obtained by integral calculus:

$$v = \frac{y^2 \pi x}{n+1}$$

It is equal to sectional area, s, times height, h, over $(n+1)$.

The truncated volumes are developed by deducting a small top conoid from a large total conoid.

$$\text{vol. tronc.} = \frac{s_1 h_1 - s_2 h_2}{n+1}$$

In the general curve equation

$$y^2 = px^n$$

we find represented:

A. For n equal to 0, the cylinder;

B. For n equal to 1, the Apollonian paraboloid, wherein the ratio between sectional area and height is constant;

C. For n equal to 2, the cone, wherein the ratio between radius of sectional area and height is constant;

D. For n equal to 3, Neill's paraboloid, the truncated form of which is found at the basis of our trees.

The top of the tree resembles a cone or Neilloid; the main bole resembles the cylinder or the Apollonian paraboloid.

The cross section (see Par. XIII.) through a tree taken perpendicular to its axis shows a more or less circular form. Near sets of branches and near the roots, however, the outline is irregular. The center of the circle usually fails to coincide with the axis of the tree.

PARAGRAPH IV.

CYLINDER.

The cubic contents v of a cylinder are equal to the height h of the cylinder, multiplied by the sectional area s of the cylinder.

$$\text{vol. cylinder} = h.s$$

PARAGRAPH V.

APOLLONIAN PARABOLOID.

The volume v of the Apollonian paraboloid is equal to height multiplied by ½ sectional area, or equal to ½ of a cylinder having the same height and the same basal area.

$$\text{vol. apol.} = \frac{h.s}{2}$$

The volume t of the truncated Apollonian paraboloid may be ascertained as:

A. Height of trunk times arithmetical mean of top sectional area and base sectional area.

$$\text{t. apol.} = h\frac{s_1 + s_2}{2}$$

B. Height of trunk times sectional area in the midst of the trunk.

$$\text{t. apol.} = h.s_{\frac{1}{2}}$$

PARAGRAPH VI.

CONE.

The volume of the ordinary cone is equal to height of cone times 1/3 sectional area at the base.

$$\text{vol. cone} = \frac{h.s}{3}$$

The volume t of the truncated cone is equal to 1/3 height of trunk times sum total of top sectional area s_1, basal sectional area s_2, and $\sqrt{s_1 s_2}$

$$\text{t. cone} = \frac{h}{3}(s_1 + s_2 + \sqrt{s_1 s_2})$$

PARAGRAPH VII.

NEILL'S PARABOLOID.

The volume of the Neilloid equals ¼ of its height times sectional area at the base.

$$\text{vol. neil.} = \frac{h.s}{4}$$

The volume of the truncated neilloid t equals

$$\text{t. neil.} = \frac{h}{4}\left(s_1 + s_2 + \sqrt[3]{s_1 s_2}\left[\sqrt[3]{s_1} + \sqrt[3]{s_2}\right]\right)$$

wherein h denotes the height of the trunk; s_1 and s_2 the top sectional area and the basal sectional area of the trunk.

PARAGRAPH VIII.

RIECKE'S, HUBER'S AND SMALIAN'S FORMULE.

Formules of practical and scientific application, used here and abroad, to ascertain the contents of logs, are those published by Smalian, Riecke and Huber.

Riecke's formula holds good for *n* equal to 0, 1 and 2, and is almost correct for the neilloid.

Smalian over-estimates and Huber under-estimates the actual contents of the truncated cone and of the truncated neilloid.

$$\text{Riecke—Vol. of trunk} = \frac{h}{6}(s_1 + 4s_{\frac{1}{2}} + s_2)$$

$$\text{Huber—Vol. of trunk} = h.s_{\frac{1}{2}}$$

$$\text{Smalian—Vol. of trunk} = \frac{h}{2}(s_1 + s_2)$$

$S_{\frac{1}{2}}$ designates the sectional area in the midst of the trunk, whilst s_1 and s_2 represent basal sectional area and top sectional area.

PARAGRAPH IX.

HOSSFELD'S FORMULE.

The formule given by Hossfeld is:

$$\text{Vol. of trunk} = \frac{h}{4}(3\, s_{\frac{1}{3}} + s_2)$$

It holds good for cylinder, cone and paraboloid. $S_{\frac{1}{3}}$ designates the sectional area at $\frac{1}{3}$ of the height of the trunk.

PARAGRAPH X.

SIMONY'S FORMULE.

Simony's formule requires measurements of sectional areas at ¼, ½ and ¾ of the height of the trunk, thus avoiding the irregularities caused by the roots at the base and by the branches at the top of a tree-trunk.

$$\text{Vol. of trunk} = \frac{h}{3}(2\, s_{\frac{1}{4}} - s_{\frac{1}{2}} + 2\, s_{\frac{3}{4}})$$

This formule holds good for the four standard conoids.

PARAGRAPH XI.

SECTIONAL MEASUREMENT.

The formules given in Paragraphs III. to X. have, in C. A. Schenck's opinion, a historic interest only when applied to whole trees. It is much safer to ascertain the volume of a tree bole by dissecting it into (imaginary) log sections of equal length, considering each of such sections as a cylinder or as a truncated paraboloid. The shorter the length of the sections, the greater the accuracy of the result. In scientific research, the length of a section varies from 5 feet to 10 feet. Obviously, at the top of the bole an uneven length is left, which it might be wise to ascertain as a cone (or paraboloid—Bulletin 20). The volume of the total bole, from stump to tip, equals, if the length of such full section is "l," and that of the top cone is "b," and

1) if sectional areas $s_1, s_2, s_3, \ldots\ldots s_n$ are measured at the big end of each section:

$$\text{vol. bole} = \frac{1}{2}(s_1 + 2\,s_2 + 2\,s_3 \ldots\ldots + s_n) + \frac{b.s_n}{3}$$

2) if sectional areas $s_I, s_{II}, s_{III}, \ldots\ldots s_m$ are measured in the midst of each full section, and sectional area s_n at the basis of the top cone:

$$\text{vol. bole} = l\,(s_I + s_{II} + s_{III} \ldots\ldots + s_m) + \frac{b.s_n}{3}$$

The former formula is based on Smalian and the latter on Huber.

In a similar way, and with still greater accuracy, the more complicated formulas of Riecke, Hossfeld and Simony might be adapted to sectional measurements.

Remark: If the diameter in the middle of a log is larger than the arithmetical mean of the end diameters, then the log contains more volume than the truncated cone, and *vice versa.*

If the sectional area at the midst of the log is larger than the arithmetical mean of the end sectional areas, then the log contains more volume than the truncated paraboloid, and *vice versa.*

PARAGRAPH XII.

MEASURING THE LENGTH OF A LOG.

The length of a log is measured with tape, stick or axe handle. In American logging, logs are usually cut in lengths of even feet, increased by an addition of two inches to six inches, which addition allows for shrinkage, for season checks, for damage to the log ends inflicted by snaking or driving, and for the trimming in the saw mill required to removed such end defects.

In Continental Europe, the standard log lengths are multiples of even decimeters. An excess-length of up to eight inches is neglected.

Crooked logs are made straight by deductions either from the length or from the diameter. Crooked trees should be dissected into very short logs.

The standard length of a New England log is 13 feet.

In the case of big logs, great care must be taken by the sawyers to obtain end-cuts perpendicular to the axis of the log.

The sum of the lengths of logs cut from a tree is termed "used length." The total length of that portion of a bole which is merchantable under given conditions is called "merchantable length."

PARAGRAPH XIII.

MEASURING THE SECTIONAL AREA.

The sectional areas are ascertained with the help of measuring tape, caliper, tree shears, tree compasses, Biltmore measuring stick, etc.

The sectional area is thus derived from the measurement either of the diameter or of the circumference.

For exact scientific investigations the planimeter or the weight of an even-sized piece of paper may be used.

It is best to consider the sectional area of a tree as an ellipse, the surface of which is:

$$\text{surface} = \frac{\pi}{4} D.d,$$

the big diameter D being measured vertically to the small diameter d.

Usually, however, the average diameter of the tree at a given point is found as the arithmetical mean of the big and small diameter at that point measured crosswise and not as the square root of the product of such diameters. Since

$$\frac{D+d}{2} > \sqrt{D.d},$$

the average diameter is invariably, though slightly, over-estimated by crosswise measurement. Hence it is wise to drop, as an arbitrary offset, the excess of fractions of inches over full inches.

The arithmetical mean of the sectional areas belonging to diameters measured crosswise leads to still greater mistakes.

PARAGRAPH XIV.

INSTRUMENTS FOR MEASURING DIAMETERS.

Log calipers are made of pyrus wood or of metal. American make (Morley Bros., Saginaw, Mich.) cost $4.00 each. The moving leg of the caliper is kept in place by a spring or a screw or a wedge.

The best European makes are the "Friedrich" and the "Heyer and Staudinger." Wimmenauer's "addition-caliper" counts the trees and adds their sectional areas automatically.

Short legged calipers, named "Dachshunds" by C. A. Schenck, can be used for trees the radius of which exceeds the length of the legs. The diameter is, in that case, indirectly found by the help of the secant joining the tips of the legs, which are about 5" long.

"Tree compasses," opening from six inches to thirty-six inches, and made of nickel-plated steel, cost (at Morley Bros.) $7.50. "Tree shears" (Treffurth) find the angle formed by the shear-legs when pressed against the tree and directly derive therefrom the diameter or the sectional area of the tree.

The "diameter tape" slung around the tree usually yields too large a diameter, since the circle embraces the maximum of surface by the minimum of length.

The "Biltmore Measuring Stick" can be well used in timber cruising. It requires the exact adjustment of distance between eye and fist of observer (usually 26 inches), and gives directly the diameter at the point of the stick where the sight line passes the tree tangentially. The stick is held horizontally against the tree.

26-INCH BILTMORE MEASURING STICK.

Length on the stick.	Diameter with bark.	Contents of butt log.	Contents of two logs.	Contents of three logs.
2.8″ 5.4″ 7.7″ 9.9″	3″ 6″ 9″ 12″	Allowing three inches for bark and three inches for taper, per log; assuming that all logs are 14′ long.		
11.9″	15″	22 ft. b. m.	29 ft. b. m.	39 ft. b. m.
13.8″	18″	56 " "	78 " "	85 " "
15.6″	21″	106 " "	162 " "	184 " "
17.3″	24″	171 " "	277 " "	333 " "
18.9″	27″	253 " "	424 " "	530 " "
20.4″	30″	350 " "	603 " "	774 " "
21.9″	33″	463 " "	813 " "	1066 " "
23.3″	36″	591 " "	1054 " "	1404 " "

Mr. Snead recommends to measure the circumference outside the bark at the big end and to divide the result by 4. He claims that the quotient yields the diameter at the small end inside bark in such a way as to offset mistakes made by Doyle, who under-estimates small logs and over-estimates big logs. Snead's suggestion is good, provided, that the cross section of the log is fairly circular, and that the difference between the small diameter inside bark at the small end and the big diameter outside bark at the big end, amounts to about 7 inches.

Diameter at small end inside bark.	Contents of 16 foot logs, in feet b.m.		
	Doyle.	Snead.	Actual saw cut.
10 inches	36′	81′	70′
15 "	121′	169′	157′
20 "	256′	289′	279′
25 "	441′	441′	436′
30 "	676′	625′	628′
35 "	961′	841′	856′

The multiples of sectional area (derived from the diameter in inches, but expressed in square feet) by length of log are readily obtained from cylinder tables published by various authors. The log scale or log rule used by the lumbermen (Lufkin rule) gives at a glance the contents of logs 8 to 20 feet long, according to their diameter.

PARAGRAPH XV.

UNITS OF LOG MEASUREMENT IN THE UNITED STATES.

The units of log measurement used in the United States differ greatly. Graves' Handbook gives 43 "rules." The rules can be subdivided into three main grops:

Board feet group (Par. XVI.);
Standard log group (Par. XVII.);
Artificial cubic foot group (Par. XVIII.).

PARAGRAPH XVI.

BOARD-RULES.

A foot board measure is a superficial foot one inch thick, in boards one inch or more in thickness. It is a superficial foot, irrespective of thickness, in boards less than one inch in thickness.

The "board rules" merely guess at the number of feet board measure obtainable from logs of a given diameter. The guess is based upon either graphical considerations, circles of specified diameters being subdivided into parallelograms 1¼ inch thick (diagram method), or else on mathematical considerations, with a view to the fact that a cubic foot of timber should theoretically yield 12 board feet of lumber, whilst the actual loss for slab, saw kerf, etc., will reduce the output by 30% to 50%. In the Biltmore band saw mill, by over one thousand tests, the actual loss for logs 12 inches to 40 inches in diameter has been found to amount to 30%, or close to 1/3. Consequently, it is safe to say that the band saw obtains from a cubic foot of log 8 board feet of lumber.

The number of board feet which a log actually yields depends on:

1. The actual cubic volume of a cylinder having the length and smallest diameter inside bark of the log.
2. The defects of the log (heart rot, wind shake, bad knots, crooks), which are usually eliminated by edger or trimmer.
3. The gauge of the saw, on which the saw kerf depends. The kerf of band saws amounts to ⅛ inch, of circular saws to usually ¼ inch, of inserted tooth saws (of large diameter) to ⅜ inch, of resaws to 1/16 inch.
4. The exactness of the work, especially depending on trueness of saw, proper lining of saw and sawyer's skill; further, on the exactness of the setworks.
5. The thickness of boards obtained; the minimum width of boards permitted; the amount of lumber wasted in the slabs; shrinkage in drying.

The following table compares the contents of logs in cubic feet with their contents in feet board measure as found by C. A. Schenck through a thousand tests of actual yield in yellow poplar, as given by Doyle's rule and by Lumberman's Favorite rule.

The figures given in columns c, f and i show the contents of a log in feet board measure after Schenck's findings, Doyle's and Favorite rules. They are converted into cubic feet (columns d, g, and j) by dividing by 12. The loss incurred in sawing is shown by percentages (columns e, h, k) representing the ratio between the actual cubic contents of a log (as given in column b), and the cubic contents of inch boards (columns d, g, j) obtained from such log.

It will be observed that the loss in the actual yield according to Schenck forms a nearly constant proportion of the cubic contents of a log in the case of all diameters, whilst, according to Doyle's and Favorite rules, the figures of loss vary greatly.

The table refers to logs 12′ long sawed into 1-inch boards.

Diameter of Log. Inches.	Contents. Cubic Feet.	Schenck.			Doyle.			Favorite.		
		Feet b. m.	Cubic Feet.	Loss %	Feet b. m.	Cubic Feet.	Loss %	Feet b. m.	Cubic Feet.	Loss %
a.	b.	c.	d.	e.	f.	g.	h.	i.	j.	k.
8	4.2	....	....	....	12	0.9	76	....	....	....
9	5.3	....	....	....	19	1.6	70	....	....	....
10	6.5	....	....	....	27	2.3	65	....	....	....
11	8.0	....	....	....	37	3.1	61	....	....	....
12	9.4	78	6.5	31	48	4.0	57	49	4.1	56
13	11.0	96	8.0	27	61	5.1	54	62	5.2	53
14	12.8	112	9.3	27	75	6.3	51	74	6.2	52
15	14.7	129	10.7	27	91	7.6	48	90	7.5	49
16	16.8	146	12.2	27	108	9.0	46	107	8.9	46
17	18.9	162	13.5	29	127	10.6	44	125	10.4	45
18	21.2	180	15.0	29	147	12.3	42	148	12.3	42
19	23.6	197	16.4	30	169	14.1	40	170	14.2	39
20	26.2	212	17.7	32	192	16.0	39	186	15.5	41
21	28.9	230	19.2	34	217	18.1	37	214	17.8	38
22	31.7	248	20.7	35	243	20.3	36	243	20.3	36
23	34.6	266	22.2	36	271	22.6	35	268	22.3	36
24	37.7	298	24.8	34	300	25.0	33	294	24.5	35
25	40.9	331	27.6	32	331	27.6	32	326	27.2	33
26	44.2	362	30.2	32	363	30.3	31	358	29.8	33
27	47.7	394	32.9	31	397	33.1	30	390	32.5	32
28	51.3	422	35.2	31	432	36.0	30	422	35.2	31
29	55.0	456	38.0	31	469	39.1	29	448	37.3	32
30	58.9	488	40.7	31	507	42.3	28	474	39.5	33
31	62.9	518	43.2	31	547	45.6	27	509	42.4	33
32	67.0	556	46.3	31	588	49.0	27	544	45.3	32
33	71.3	596	49.7	30	631	52.6	26	589	49.1	31
34	75.7	634	52.8	30	675	56.3	26	634	52.8	30
35	80.2	670	55.8	30	721	60.1	25	662	55.2	31
36	84.8	710	59.2	30	768	64.0	25	690	57.5	32
37	89.6	755	62.9	30	817	68.1	24	734	61.2	32
38	94.5	806	66.7	29	867	72.3	23	778	64.8	31
39	99.5	850	70.8	29	910	75.8	24	824	68.7	31
40	104.7	901	75.0	28	972	81.0	23	870	72.5	31

From column e it is evident that the bandsaw wastes close to 1/3 of the cubic contents of a cylindrical log, or 4′ b. m. out of every cubic foot.

Consequently, from hardwood logs 12 feet to 16 feet long, the bandsaw will obtain the following *actual* number of feet b. m. (in 4/4" thickness):

(a) from 12 foot logs: $\frac{D^2 \times 0.78 \times 12 \times 8}{144}$, almost equal to $D^2 \times .5$

(b) from 14 foot logs: $\frac{D^2 \times 0.78 \times 14 \times 8}{144}$, almost equal to $D^2 \times .6$

(c) from 16 foot logs: $\frac{D^2 \times 0.78 \times 16 \times 8}{144}$, almost equal to $D^2 \times .7$

Hence it can be stated generally, for logs of medium length "L," that their contents in band-sawed inch lumber approximate

$$\frac{D^2}{10} \times \frac{L-2}{2} \text{ feet b. m.}$$

PARAGRAPH XVII.

STANDARD RULES.

The standard rules do not estimate the contents of a log according to output in board feet, but compare the log with a local average log. Such average logs used to have, in the Northeast, formerly, a diameter of either 19 inches (Adirondacks) or 22 inches (Saranac River) or 24 inches, and were in all cases 13 feet long.

The 19 inch standard log rule is known as Dimick's rule. Here the "standard" or "market" is a log 13 feet long and 19 inches thick. On a 22 inch base it is 13 feet long and 22 inches thick. On a 24 inch base it is 13 feet long and 24 inches thick.

The standard contents of a given log are found by dividing the cubic volume of the standard log into the cubic volume of the given log.

$$\text{v (in standards) equals: } \frac{d^2 \times h}{19^2 \times 13}$$

Scientifically and mathematically the standard rules are superior to the board rules. One market, at a 19 inch base, is generally considered equivalent to 200 board feet; at a 22 inch base, to 250 board feet; at a 24 inch base, to 300 board feet.

It is easily shown that the output of small logs is not as badly under-estimated, and the output of big logs not as badly over-estimated on the basis of standard rules, as is the case when Doyle's rule alone is applied.

PARAGRAPH XVIII.

CUBIC FOOT-RULES.

In a third group of rules, a new unit, the "artificial cubic foot," is introduced. This group of rules is established by law in Maine and New Hampshire. (See Graves' Handbook, page 45.)

The artificial cubic foot corresponds with a log 12 inches long and 16 inches thick, which naturally contains 1.4 cubic feet. The rule assumes that 40/140 or 28.5% of a log goes to waste in the sawing process as dust or slab.

To quickly transform artificial cubic feet into board feet, the laws prescribe certain arbitrary equivalents, instead of allowing 12 board feet to equal one artificial cubic foot of timber. In New Hampshire, 10 board feet equal one artificial cubic foot. In Maine, 11.5 board feet equal one cubic foot. The rules might be used in connection with a cylinder table, deducting 28.5% from the table data and multiplying the remainder by 10 or by 11.5.

REMARK: According to the Forest Reserve Manual, logs over 24 feet long are treated as 16 foot logs and fractions thereof.

PARAGRAPH XIX.

EQUIVALENTS.

One cubic meter equals 35.316 feet or 1.308 cubic yards.

1,000 board feet of sawn lumber, 1 inch and more thick, correspond with 2.36 cubic meters of sawn lumber.

A product of one cubic meter per hectar (2½ acres) equals a product of 14 cubic feet per acre.

One gallon equals 231 cubic inches in liquid measure, or 268.8 cubic inches in dry measure (which is also ½ peck).

One liter equals 1.0567 quarts; one cubic foot equals 7.4805 gallons or 28.3 liters.

Logs yielding when split one cord of wood, will yield, when sawn:

For log diameter:	Feet board measure:
20″	515′
25″	566′
30″	605′
35″	629′
40″	649′

The Forest Reserve Manual adopts 2 cords as equivalent to 1,000 cubic feet b. m., provided that the wood is split from timber 10 inches in diameter and over.

TABLE SHOWING RELATIVE CONTENTS OF LOGS WITHOUT BARK.

Log diameter.	5″	10″	15″	20″	25″	30″
1 cubic foot equals ft. b. m. Doyle	......	4.12	6.2	7.3	8.09	8.64
1 cubic meter per hectar corresponds with ft. b.m. Doyle per acre:	......	57.68	86.8	102.2	113.26	120.96
1 cubic meter of log yields ft. b. m. Doyle:	44.8	145.5	218.2	258.8	285.7	303.7
1000 ft. b. m. Doyle equal cubic ft:	787.4	242.7	161.8	136.4	123.6	116.3
1000 ft. b. m. Doyle equal cubic meters	......	6.87	4.39	3.86	3.5	3.29
Artificial cubic feet per 1 ft. of log	......	.4	.9	1.56	2.45	3.51
No. of legal N. H. feet b. m. per 1 ft of log:	......	4.	9.	15.6	24.5	35.1
Ft. b. m. Doyle per 1 ft. of log	......	2.3	7.5	16.	27.5	42.5

PARAGRAPH XX.

XYLOMETRIC METHOD.

The so-called "physical methods," by which the volume of a (particularly irregular) piece of a tree may be accurately found, require either the submersion of the piece in water (xylometric method) or the weighing of the piece after finding its specific gravity (hydrostatic method, § XXI.).

The xylometric method can be applied in three ways, thus:

a. Submerge the wood in a graded cylinder partly filled with water and find the water level before and after submersion.

b. Submerge the wood in a barrel partly filled with water; dip out the water with a gallon measure until the water is as low as it was before submersion. The number of gallons dipped out equals the volume of the wood submerged. One gallon equals 231 cubic inches.

c. Place a piece of wood in an empty barrel of known contents; fill to the rim with water by the gallon. The difference between the known contents and the number of gallons required gives the quantity of wood in gallons.

In *a, b* and *c* it is necessary to use wood dry on the outside, to leave the wood in the water a short time only, and to stir it up while in the water so as to remove air bubbles.

PARAGRAPH XXI.

HYDROSTATIC METHOD.

The hydrostatic method deals with specific gravities. Specific gravity is weight of an object divided by the weight of an equal volume of water. In the metric system, it equals weight in kilograms over cube-decimeters of volume. The specific gravity is found by weighing a given body, and then weighing it again immersed in water. It equals weight outside water over loss of weight submerged in water. The division of the metric weight of a large body by the specfic gravity of a sample piece yields the volume of the body in cubic decimeters.

Since wood is lighter than water, usually, a piece of lead must be attached to the wood in order to submerge it. There must be ascertained:

1. The absolute weight of the piece of lead, H;
2. The weight of the same piece submerged in water, h;
3. The absolute weight of the wood and of the lead, G;
4. The weight of wood and lead submerged in water, g.

The weight of the wood alone is, consequently, (G—H).

The specific gravity of the wood is

$$s = \frac{G - H}{(G - g) - (H - h)}$$

The volume, in cubic feet, of a quantity of wood weighing *n* pounds, and having the specific gravity *s*, is

$$\text{volume} = \frac{n}{s} \times \frac{1}{63} = \frac{16n}{1000s}$$

The figure 63 represents the weight in pounds of one cubic foot of water.

The specific gravity of wood is greatest close to the stump and in the branches. For some species the outer layers show the greatest specific gravity; for others the inner layers.

Species.	Spec. gravity, air dry.	Weight of lumber per 1000 ft. b. m. in lbs.	Weight of one cord in lbs.
White oak......	.75	3900	3985
Beech.........	.71	3692	3767
Hard maple....	.66	3432	3510
Yellow pine....	.52	2704	2761
Spruce.........	.45	2340	2391
White pine.....	.39	2028	2069

Rules to convert specific gravity into weight per 1,000 feet board measure or into weight per cord read as follows:

1. Multiply specific gravity by 5,200. The result is the weight of lumber per 1,000 feet board measure in pounds.

2. Multiply specific gravity by percentage of solid wood contained in a stacked pile; then multiply the product by 8,050. The result gives the weight per cord in pounds.

PARAGRAPH XXII.

FACTORS INFLUENCING THE SOLID CONTENTS OF CORDWOOD.

The solid contents of wood stacks depend on the size and the form of the pieces composing them and on the method of piling. The solid contents of a cord can be found only by the methods described in Paragraphs XX. and XXI. The European experiment stations have collected data to that end on a very large scale, and have established the following laws:

a. The bigger the pieces of wood in a stack, the larger are the solid contents of the stack.

b. The longer the pieces of wood, the smaller are the solid contents of the stack.

c. Pieces piled parallel and tightly greatly increase the solid contents of the stack.

d. During the drying process, hardwoods shrink approximately by 12%, and soft woods by 9%. The shrinkage is partly offset by the cracking of wood.

These rules are important in the pulp, tanningwood and firewood trade.

PARAGRAPH XXIII.

REDUCING FACTORS FOR CORDWOOD.

The countries using the metric system pile wood in space cubic meters. One space cubic meter equals .274 cord. The pieces contained therein are 3.28 feet long. For such conditions the following figures hold good:

a. First class split wood, obtained from sound pieces 12 inches in diameter, contains per cord 102.4 cubic feet of solid wood (reducing factor 80%).

b. Composed of inferior split wood, obtained from round pieces having a diameter of 6 inches, a cord contains 96 cubic feet of solid wood (reducing factor 75%).

c. In heavy, round branch wood (diameters of about 6½ inches) 87 cubic feet of solid wood are found in a cord (reducing factor 68%).

d. In round pieces of branch wood, 4 inches in diameter, 77 cubic feet are found in a cord (reducing factor 60%).

e. In faggots, 25 to 51 cubic feet make a cord (reducing factor 20% to 40%).

The percentages for broad leafed species are smaller than those for conifers, owing to the latter's straight growth.

At Biltmore, one cord of 8 foot split oak contains about 80 cubic feet; one cord of kindling finely split about 90 cubic feet; one cord of blocks 12 inches long about 100 cubic feet of solid wood.

In the sale of tannin wood it is well to sell 5 foot sticks finely split rather than heavy blocks 4 feet long.

In the sale of pulp wood, 12 foot sticks yield much higher returns than 4 foot sticks, if sales are made by the cord.

PARAGRAPH XXIV.

LOCAL PECULIARITIES WITH REFERENCE TO STACKED WOOD.

Tannin and pulp wood industries sometimes figure at a cord containing 160 stacked cubic feet, equal to 1¼ ordinary cords of 128 stacked cubic feet.

After Graves (page 65), a cord of firewood is in certain sections understood to be 5 feet long, 4 feet high and 6½ feet wide.

Under "a cord foot" is understood a stack 1 foot by 4 feet by 4 feet (⅛ cord or 16 stacked cubic feet).

Under "a cylindrical foot" is understood a stacked cubic foot equal to 1/128 cord. The number of such feet (a misnomer for stacked cubic feet) in a stick is

$$\frac{d^2 \times l}{144}$$

(*l* equals length of stick in feet; *d* equals its diameter in inches).

In New England, a cord of pulp wood is sometimes measured by calipering the round sticks composing it, and tables are constructed to facilitate calculation. Proceed as follows:

Ascertain diameter of sticks in inches, square them singly, total the results and divide by 144. Multiply the quotient by length of sticks in feet and divide by 128.

PARAGRAPH XXV.

BARK.

Bark is usually sold and bought by the cord. The tanneries, however, instead of measuring a cord of 128 cubic feet, apply the misnomer "one cord" to a weight of 2,240 lbs. (the long or European ton).

Twelve cords of bark fill one common (old) freight car.

A stack of bark contains from 30% to 40% solid bark. The specific gravity of fresh oak bark is 0.874; dried, it is 0.764.

The bark of white oak has been found (at Biltmore), to comprise:

In trees 20 years old, 55% of the wood, or 35% of the whole bole;
In trees 60 years old, 41% of the wood or 28% of the whole bole;
In trees 100 years old, 29% of the wood or 22% of the whole bole;
In trees 140 years old, 21% of the wood or 17% of the whole bole.

Chestnut oak peeled at Biltmore yields the following results per tree, arranged according to the diameter of the trees 4½ feet above ground:

Diameter of tree chest high in inches.	Dry Bark in Kilogram = $\frac{1}{1000}$ cord, per Tree.		
	Minimum	Average.	Maximum.
6	5	13	27
7	6	17	36
8	8	24	48
9	12	33	61
10	18	45	77
11	26	60	95
12	37	73	114
13	50	88	135
14	65	105	158
15	81	126	180
16	98	150	204
17	116	172	234
18	136	195	266
19	159	224	314
20	181	250	365
21	205	275	...
22	230	305	...
23	265	336	...
24	275	375	...

If the percentage of bark in a log or tree (scaled with the bark) is *p*, then the bark percentage in ratio to the solid wood alone is:

$$\frac{100 \times p}{100 - p}$$

According to thickness of bark and diameter of logs, the following percentages can be given for the ratio:

$$\frac{\text{bark}}{\text{bark plus timber}}$$

Diameter with bark—inches.	Thickness of bark.			
	½″	1″	1½″	2″
10	19%	36%	51%	64%
15	12%	24%	36%	46%
20	9%	19%	27%	36%
25	7%	15%	22%	29%
30	6%	12%	19%	24%

SECTION II.—VOLUME OF STANDING TREES.

PARAGRAPH XXVI.

METHODS OF OBTAINING THE VOLUME OF STANDING TREES.

The volume of standing trees may be ascertained

By estimating it (Par. XXVII.);
By measuring heights and diameters (Par. XXVIII.);
By the form factor method, which combines estimates and measurements (Par. XXIX. f.f.).

By these means can be obtained the volume of the bole (from roots to top bud), or the volume of saw timber in any of the 43 log scales, or the volume of firewood in cords, etc., or the total volume, including brush and roots.

Under "used volume," Circular 445 of the United States Bureau of Forestry understands the sum of the volumes of logs cut from a tree; under "merchantable volume" the total volume of that portion of the tree which is merchantable under certain conditions.

PARAGRAPH XXVII.

HELPS AND HINTS TO FIND THE VOLUME OF STANDING TREES.

It is difficult to estimate the cubic contents, wood contents or lumber contents of a standing tree. In the case of estimates in board feet, the result depends on the exclusion or inclusion of crooked and defective pieces, on the taper of the bole, on the soundness of the heart, and on the minimum diameter admissible in the top log. Compare end of Paragraph XXXII.

Most hazardous is the volume estimate of over-aged trees, especially in the case of hardwoods (chestnut).

The following helps might guide the novice:

1. The volume of a sound tree bole, in cubic meters, is equal to

$$\frac{1}{1000} D^2$$

for example, diameter (breast high) 30 c. m.; contents 0.9 cubic meters.

2. The contents of a standing tree, in cubic feet, are about

$$\frac{2}{10} D^2$$

for example, diameter (breast high), 25 inches; contents (from butt to tip), 125 cubic feet.

3. The number of feet Doyle in a tall sound tree equal

$$\frac{3}{2} D^2$$

for example, diameter (breast high), 20 inches; contents 600 feet board measure.

4. The contents of a tree in feet Doyle approximate, assuming that the bole is cut into 16 foot logs, and that the tree tapers 2 inches per log:

$$N \times D\,(D - 12)$$

wherein *N* represents the number of logs obtainable; *D* the diameter of the butt log without bark at breast height.

5. The cordwood contained in a sound bole is:

$$\frac{D^2}{1000} \times C$$

wherein *C* amounts to:

1.5 in the case of trees 8″ through;
2.0 in the case of trees 16″ through;
2.5 in the case of trees 24″ through.

PARAGRAPH XXVIII.

SCIENTIFIC METHODS OF ASCERTAINING THE CUBIC CONTENTS OF STANDING TREES BY MERE MEASUREMENT.

The cubic volume of the bole, on the basis of diameter measurement and height measurement, in the case of a standing tree, may (with the help of climbing iron, ladders, camera or instruments constructed for the purpose) be figured out:

1. According to the formulas of Hossfeldt, Riecke and Simony. In this case, the upper diameters must be measured indirectly.

2. According to Huber's and Smalian's formulas, the diameters of equal sections of the trees being indirectly measured.

3. According to Pressler's formula, which is, for the volume of the bole lying between chest height and top bud, 2/3 of sectional area "S" at chest height times "rectified" height of bole. The rectified height "r" is the distance of chest height from that point of the tree bole which has ½ of the chest height diameter (from the "guide point"). The equation 2/3 r x S holds good for paraboloid, cone and, at a slight mistake, for the neilloid.

The volume of that part of the tree bole which lies below chest height is ascertained (as a cylinder) as being equal to sectional area chest high times 4.5.

REMARK: 4.3′ is the chest height usually recognized by the authors; Pinchot adopts 4.5′.

The Pressler formula does not hold good for truncated boles.

PARAGRAPH XXIX.

FORM FACTOR METHOD.

The form factor or form figure method relies on the measurement of the sectional area—usually the one at breast height,—the measurement or the estimation of the total height and the estimation of the form figure.

The form factor is a fraction expressing the relation between the actual contents of a tree, in any unit, and the ideal contents which a tree would have if it were carrying its girth (like a cylinder) up to the top bud undiminished.

The form factor may be given in reference to the volume of the entire tree, inclusive of branches in cubic feet; or in reference to the volume of the bole only; or in reference to the merchantable part of the bole; in the latter case either in feet board measure or in standards or in cords.

Historic Remarks: Some of the older authors on mensuration saw in the cone and not in the cylinder the ideal form of the tree, basing their form factors on the ideal volume $\frac{s \times h}{3}$.

PARAGRAPH XXX.

KINDS OF FORM FACTORS MATHEMATICALLY.

Scientifically we distinguish between:

1. The absolute form factors which have reference only to the volume standing above chest height. They can be readily ascertained with the help of Pressler's formula. Generally speaking, V equals Sx H x F. After Pressler, V equals S x 2/3 x r; thus $\frac{\frac{2}{3} r}{H}$ equals F.

For the cone the absolute form factor is one-third; for the neilloid one-fourth; for the paraboloid one-half, whatever the height of the tree may be. Hans Rienicker, the author of these form factors, finds for trees up to 50 years old a form figure of 35% to 43% (in regular, dense German woods); in trees 50 to 100 years old, F increases up to 50%; thereafter occurs a slight decrease below 50%.

2. The normal form factors which were recommended by Smalian, Pressler and other old-time authors. They have reference to the entire volume and necessitate the measurement of the diameter at a given fraction (usually 1/20) of the total height of the tree. Frequently, in case of tall trees, the point of measurement cannot be reached from the ground. The bole form factor for diameters measured at 1/20 of the height is: For a paraboloid, 0.526; for a cone, 0.369; for a neilloid, 0.292. These form factors, like the absolute form factors, are independent of the height.

3. The so-called "common form factors" which do not express, as a matter of fact, the form of the tree, since they do not bear any direct ratio to the degree of the tree curve. They should be termed, more

properly, "reducing factors." These form factors alone are nowadays practically used. They are based on diameter measurements, chest high, and have reference not merely to the bole of the tree, but as well to any parts of the bole, to root and branch wood, to saw logs, etc. These form factors depend entirely on the height. If, for instance, a paraboloid is one rod high, the form factor is 0.673; and if it is 8 rods high, the form factor is 0.517.

PARAGRAPH XXXI.

KINDS OF COMMON FORM FACTORS IN EUROPEAN PRACTICE.

The following kinds of form factors may be distinguished:

1. Tree form factors. The tree is considered as bole plus branches.

2. Timber form factors. The term timber, in Europe, includes all parts of the tree having over 3 inches diameter at the small end.

3. Bole form factors. Bole is the central stem from soil to top bud. For America, form factors would be of great value ascertained by exact measurements and arranged according to diameter, height and smallest log diameter used.

Tables of form factors may be constructed, for instance, for shortleaf pine, on the basis of Olmsted's working plan, pages 17-33.

PINUS ECHINATA.

Diameter.	Merchantable length of bole.	Cubic feet Ideal cylinder.	Form fig.	Contents b. m. Doyle.
16″	36′	50.3	3.6	180′
18″	47′	83.1	3.6	300′
20″	51′	112.1	4.0	440′
22″	56′	147.8	4.0	600′
24″	59′	185.3	4.2	780′
26″	61′	224.9	4.4	980′
28″	62′	263.1	4.5	1190′
30″	62′ 6″	306.7	4.6	1420′
32″	63′	351.8	4.7	1680′
34″	63′ 6″	400.3	4.8	1930′
36″	64′	457.3	4.9	2200′

The influence of age, soil, density of stand, height, diameter and species on the various form factors, with cubic measure as a basis, has not been fully ascertained.

For the tree form factor, the most important influence, in the case of trees less than 150 years old and raised in a close stand, seems to be that of the height of the tree; with increasing height the tree form factor decreases—*e. g.*, for Yellow Pine:

One pole high	.93
Two poles high	.65
Four poles high	.53
Six poles high	.49

The timber form factor, based on cubic measure of a tree, rises with increasing age and increasing height up to a certain point (for Yellow Pine at 3 poles), provided that the term timber includes all stuff over 3 inches in diameter. The timber form factor is a function more of the diameter than of the height. Timber form factors of Yellow Pine are:

Trees 1 pole high	.07
Trees 2 poles high	.36
Trees 3 poles high	.48
Trees 4 poles high	.46
Trees 7 poles high	.45

The timber form factor in shade bearers is a little higher than that in light demanders (within an age limit of 150 years, for trees in close stand).

The bole form factor can be found, in fact, only for species forming a straight bole free from large branches (hence especially for conifers). The bole form factors, to begin with, are large; with increasing height, they decrease gradually to a par with the timber form factors—*e. g.*, for Yellow Pine:

1 pole high	.70	3 poles high	.49
2 poles high	.55	4 poles high	.47
7 poles high	.45		

European common form factors are collected by thousands of measurements taken in a large variety of localities. It must be remembered that a form factor read from a table is never applicable to an individual tree, and is only applicable to an average tree amongst thousands.

For trees less than 120 years old, the branch wood (stuff less than 3 inches in diameter) comprises from 15% to 28% of the entire tree volume; this figure, in the case of broadleaved species, rises from 25% up to 33%. For trees as now logged in America, the branchwood percentage is naturally very much smaller.

$$\text{The tree form factor equals } \frac{\text{stump plus bole plus branches}}{\text{ideal cylinder}}$$

$$\text{The timber form factor equals } \frac{\text{all stuff having over 3'' diameter}}{\text{ideal cylinder}}$$

$$\text{The bole form factor equals } \frac{\text{bole from ground to tip}}{\text{ideal cylinder}}$$

By form height is meant the product of height (total height of tree) times form factor, or else that much of the height of the ideal cylinder which the tree volume, poured into the ideal cylinder, would fill. Since the form factor on the whole decreases with increasing height, the form height is a fairly constant quantity; at least for trees of merchantable size. Hence the helps and hints given in Paragraph XXVII (to quickly find the volume of standing trees from mere diameter-measurement) may lay claim to correctness in many cases. For instance: The cubic contents of a tree are supposed to be equal to

$$\frac{\pi}{4} \times \frac{D^2 \times H \times F}{144}$$

After Paragraph XXVII., 2, these contents are also

$$\frac{2}{10} \times D^2$$

$$\frac{D^2}{5} = D^2 \times 78 \times H \times F$$

$$H \times F = \frac{288}{7.8} = 37$$

As a matter of fact, the form height of trees 1 foot to 2 feet in diameter is close to 37. And for such trees the equation holds good.

The form height may also be defined as "volume (standards, cords, bark, etc.) per square foot of sectional area chest-high."

PARAGRAPH XXXII.

MEANS FOR EXACT MENSURATION OF STANDING TREES.

The means used to find the exact solid volume of standing trees are instruments for measuring the total height of the merchantable length of a tree; instruments for measuring the diameter at given heights; further tables based on scientific research and experience, or tables merely meant to facilitate calculation. Instruments for measuring diameters far above ground are needed for the use of the formulas given by Riecke, Hossfeldt, Pressler, etc.

The six paragraphs following next dwell upon these topics.

PARAGRAPH XXXIII.

MEASURING THE HEIGHT OF A STANDING TREE.

The height of a tree can be measured by comparing its shadow with the shadow of a stick, say 10 feet long. The "Lumber and Log Book" gives another old method (page 133) of height measurement. If the observer places himself in such a way that a small pole stands between him and the tree at a distance e, and if he marks on the pole two points where his sight, directed towards the top and base of the tree, touches the small pole, and if he further ascertains the distance *E* separating him from the tree, then the height of the tree H equals

$$\frac{E}{e} \times h$$

wherein h represents the number of feet between the two points marked on the pole.

Instruments (hypsometers) for height measuring are sold in many forms. The following are frequently used: Rudnicka's instrument; Pressler's "Measuring Jack;" Faustmann's "Mirror Hypsometer;" Weise's Telescope; Kœnig's "Measuring Board;" Brandis' "Clinometer;" Klausner's instrument; Christen's "Non plus ultra."

Compare Woodman's Handbook, pages 136 to 137, for staff method; page 138 for Faustmann's; page 140 for tangential clinometer; page 143 for mirror clinometer.

Christen's stick is not accurate enough for the measurement of trees over 100 feet high. It does not require the measurement of distances. Its form is improved by Pinchot.

PARAGRAPH XXXIV.

FACTORS INFLUENCING THE EXACTNESS OF HYPSOMETRICAL OBSERVATIONS.

The best results are obtained if the distance between tree and observer equals the height to be measured. In sighting towards the spreading top of a hardwood tree, the observer is apt to overrate the height, the tip being buried in the spreading crown. The line of sight strikes the edge of the crown instead of striking the apex of the crown.

Timber cruisers are usually satisfied to determine the number of logs obtainable from the bole instead of determining the length of the bole. As a matter of fact, where the tree furnishes saw logs only, the total height of the tree is a less reliable indicator of the total contents than the length of the merchantable bole.

Instruments like Faustmann's, Kœnig's and Pressler's cannot be used in windy and rainy weather. Dense undergrowth and dense cover overhead render exact measurement impossible.

PARAGRAPH XXXV.

INDIRECT MENSURATION OF DIAMETERS.

The following instruments are used to measure the diameter of the tree at any point of bole:

a. Winkler, an addition to Kœnig's measuring board.
b. Klausner.
c. An ordinary transit.
d. Wimmenauer's telescope.

PARAGRAPH XXXVI.

PRESSLER'S TELESCOPE.

Pressler's telescope is used to find the "guidepoint" and the "rectified height," as defined in Paragraph XXVIII., 3. The diameter chest-high is taken between the nails at the end of the instrument. Then the telescope is pulled out to a length double the original, divided by the cosin of the angle found between the horizon and the probable sight to the "guidepoint" (at which the observer expects to find one-half the diameter chest-high). Thus, actually, the instrument merely examines the correctness of an original estimate.

The Pressler telescope can be used for finding the merchantable length of any bole. Merely place a stick, equal in length to twice the minimum diameter permissible in a merchantable log, at the foot of the tree, catch it between the nail points and proceed as described.

PARAGRAPH XXXVII.

AUXILIARIES FOR CALCULATION.

Auxiliaries for calculation are:

1. Sectional area tables (Schlich, Vol. III.); engineering books like Haswell's; Bulletin 20; also Green.)
2. Ideal cylinder tables (Schlich and Bulletin 20).
3. Multiplication tables and logarithm-tables.
4. Tables showing contents of logs in any of the 43 rules, according to length and diameter.

PARAGRAPH XXXVIII.

TREE VOLUME-TABLES.

Tree volume tables have been constructed on a very large scale for the leading species in the old country. In the United States, the Government is now beginning to make such tables. The tables give the cubic, lumber and cord wood contents of trees, according to species, diameter and sometimes according to total height and merchantable height (number of logs).

Bulletin 36 reprints the following tree volume tables:

A. According to diameter measure merely.

Page 92. Adirondack White Pine, volume in standards.
Page 94. Pennsylvania Hemlock, volume in feet, b. m., Scribner.
Page 94. Adirondack Hemlock, in standards.
Page 95. Adirondack Spruce in standards.
Page 96. Adirondack Birch, Beech, Linden, Sugar Maple in Scribner, feet, b. m.
Page 96. Adirondack Balsam, in standards.
Page 97. Adirondack White Cedar, in standards.
Page 98. Arkansas Shortleaf Pine, in feet, b. m., Doyle.
Page 98. Missouri Ash, Elm, Maple, Cypress, Gum, Oak, Hickory, Poplar, in feet, b. m., Doyle.
Page 99. Western Yellow Pine, in feet, b. m., Doyle (Black Hills), distinguishing between the volume of first and second growth.
Page 99. Yellow Poplar in Pisgah Forest in feet, b. m., Doyle, distinguishing between good, average and poor conditions of growth.

All tables, except Yellow Poplar tables, are based on the measurement of a large number of trees. The Yellow Poplar tables are based on stem analyses of a small number of trees.

B. According to measurement of height and diameter combined.

Page 93. Wisconsin White Pine (height expressed by the number of logs obtainable from merchantable bole) in feet, b. m., Doyle.

Page 103. Adirondack Spruce expressed in feet, b. m., Scribner, the total height of trees being measured.

Page 104. The same in cubic feet.

Page 105. The same in cords for pulp wood.

Page 106. New Hampshire Spruce in feet, b. m., in New Hampshire cubic feet sanctioned by law.

Pages 108 and 111. Adirondack White Pine with bark, expressed in cubic feet.

Page 110. Adirondack White Pine in feet, b. m., Doyle.

Monographic investigation into the growth of the leading American species is of great importance. The trees of virgin forests are very defective, however, and tree tables can never be constructed giving the contents of defective trees.

SECTION III.—VOLUME OF FORESTS.

PARAGRAPH XXXIX.

SYNOPSIS OF METHODS FOR ASCERTAINING THE VOLUME OF FORESTS.

The methods used to find the volumes of entire forests, of forest compartments, tracts, quarter sections, coves, etc., are:

1. Estimating (Par. XL.).
2. Exact calculation after measurements (Par. XLI., f. f.).
3. Combined measuring and estimating (Par. IL., f. f.).

Obviously, measuring without estimation is possible only in forests containing little unsound timber.

PARAGRAPH XL.

ESTIMATION OF FOREST VOLUME.

In primeval woods, where a few assortments only are salable and where stumpage is cheap, the estimation of stumpage necessarily takes the place of the measurement. If any measurements are taken, they are merely meant to back the estimation of the cruiser. The more defective the trees are, the more preferable is judgment and local long experience in the mill and in the woods on the side of the cruiser to mere measuring.

The volume of a wood is ascertained by cruisers' estimates in the following ways:

a. By estimating the number of trees and the volume of the average tree with due allowance for defects.

b. By counting the trees and estimating the volume of average trees with allowance for defects.

c. By estimating the volume of each tree separately, sounding it with an axe, when necessary, and judging its soundness from all sides.

The above methods (*a, b, c*) are applied either to sample plots or to sample strips or to the entire area.

A blazing hammer is often used to prevent duplication; the revolving numbering hammer might be used in case of scattering trees, so as to allow of control of the estimates by the owner, his forester or the prospective purchaser of stumpage.

In irregular forests—hardwood forests of the United States—the only safe way is separate estimating of each individual tree after careful inspecting. Incredible errors result from wholesale and rapid estimates.

In the case of even aged woods, a look at the height growth and a knowledge of the age gives a good idea of the forest's volume. Under very poor conditions of growth, the annual timber production per acre and year is as little as 15 cubic feet; under the best conditions it is as much as 250 cubic feet per acre and year. On an average (on absolute forest soil), 50 cubic feet per acre and year may be considered as the production of healthy and densely stocked forests.

PARAGRAPH XLI.

PRINCIPLES UNDERLYING THE EXACT MENSURATION OF FOREST VOLUME.

The basis of any exact measurement of volume is formed by a survey of the sectional area, combined with an account of the number of stems; sectional area and number are found by calipering (valuation survey). Whatever rule of log measurement may be at stake, the total sectional area of the forest is always of first importance for a survey of forest volume. Next in importance is the calipering of sample trees, followed by an exact survey of their volume. The ratio *r* existing between the volume of the sample trees (expressed in any unit or mixture of units) and the sectional area of the sample trees is identical with the form height (compare Par. XXXII., towards end) of the sample trees. The form height of sample trees properly selected is the form height of the forest. The sample trees are usually cut and worked up into logs, cordwood, tannin wood, etc., for the purpose of volume survey.

$$\frac{V}{S} = \frac{v}{s} = \frac{f.\ h.\ s.}{s} \quad \text{and} \quad V = S.\ f.\ h$$

If the trees of the forest are defective, the sample trees should exhibit average defects.

PARAGRAPH XLII.

FIELD WORK FOR EXACT VALUATION SURVEYS.

The valuation survey requires:

1. Calipering of all trees; the diameter is taken in inches or in multiples of inches. Each species and each height class or age class are or may be taken separately.

2. Entering the takings on tally sheets, arranged as follows:

Diameter.	Spruce.		Beech.	
	Height classes.		Height classes.	
	I	II	I	II
10″				
11″				
12″				
13″ etc.				

The larger the trees are, the bigger is the permissible interval of calipering. If trees average two feet in diameter, an interval of 3 inches is permissible, provided that a large number of trees are calipered.

It is a strange fact that the diameter measured from east to west is larger on the whole than the diameter from north to south.

PARAGRAPH XLIII.

BASAL ASSUMPTIONS.

The only assumption made in calculating the volume of the forest after Paragraph XLI. is that the form height of the sample trees equals the form height of the forest. No other estimate or assumption is being made. This premise is much safer than the assumption that the volume of the forest bears the same ratio to the volume of the sample trees which the number of trees in the forest bears to the number of the sample trees. More unsafe is the assumption that the volumes of forest and sample trees bear the ratio of the acreage occupied by the forest on the one hand and by the sample trees on the other hand.

PARAGRAPH XLIV.

SELECTION OF SAMPLE TREES.

Sample trees are selected either irregularly or after a regular plan. In the latter case, it is best to distribute them equally among the diameter classes composing the forest (Draudt-Urich method and Robert Hartig method), instead of selecting sample trees of average diameter.

It is more important that the sample trees should have proper average class-form height (and average defects) than that they should have exact average class-diameters.

PARAGRAPH XLV.

DRAUDT-URICH METHOD.

The Draudt-Urich method is in common use abroad for measuring the forest. The trees of the forest are divided into a number of classes (usually five). Each class contains an equal number of trees, class 1 containing the largest and class 5 the smallest trees. In each class an equal number of sample trees, having about the average diameter of the class, are felled and worked up into logs, cordwood, ties, poles, etc. The form height of all sample trees is obtained as the quotient of their volume (in any unit or mixture of units) divided by their sectional area. Multiplying the sectional area of the forest with this form height, the exact volume of the entire forest and its composition (logs, poles, cords, etc.) are given by one operation.

Sample trees of the average diameter of a class are found by dividing the sectional area of the entire class by the number of trees per class. It is wrong to find the average diameter by dividing the sum total of the diameters by the number of trees.

Diameter Breast High.	Number of Trees.	Diameter Classes of Trees.	Number of Sample Trees.	Average Diameter of Sample Trees.
40" 35" 30" 25"	310 240 506 1226	I	11	29"
25" 20" 15"	9 1040 1233	II	11	17"
15" 10"	1847 435	III	11	14"
10"	2282	IV	11	10"
10"	2282	V	11	10"

The advantages of the Draudt-Urich method are:

1. All sample trees can be worked up in a bunch.

2. Not only the entire volume but as well the different grades of timber, fuel, ties, etc., composing the volume are found by one operation.

A large number of sample trees are, however, required, and, since the volumes of the various classes are unequal, a negative mistake made in establishing the volume of one class is not apt to be counter-balanced by a positive mistake made in finding the volume of another class.

PARAGRAPH XLVI.

ROBERT HARTIG METHOD.

Robert Hartig's method forms tree classes containing equal sectional areas—not equal numbers of trees. An equal number of sample trees is cut in each class and worked up separately for each class. The volume of the forest is also obtained separately for each class. Otherwise, the manner of proceeding is identical with that of Paragraph XLV.

Preferable it would seem to cut in each class a number of sample trees having, in the aggregate, the same sectional area. This scheme, however, would represent the big-diameter class by an absurdly small number of samples.

PARAGRAPH XLVII.

AVERAGE SAMPLE TREE METHOD.

If average trees of the entire forest are taken as samples, then the volume of the forest is obtained with smaller accuracy.

The proportion which the different assortments of timber, wood, bark, etc., form in the entire output is not clearly shown by such sampling.

In a normal, even-aged wood the tree of average cubic volume is found by deducting 40% from the total sectional area, beginning with the deduction at the biggest end. The largest tree then left is, or happens to be, *the* average tree of the wood.

PARAGRAPH XLVIII.

EXACT MENSURATION WITHOUT CUTTING SAMPLE TREES.

Frequently the cutting of sample trees for the purpose of a valuation survey is not feasible. The volume of the forest in cubic feet—but not the assortments composing the volume—may then be ascertained as follows:

a. Take the total sectional area of the forest according to diameters and species and, if necessary, according to height classes.

b. Ascertain the bole volume of some available trees with the help of Pressler's tube or by indirect measurement of heights and diameters.

c. Proceed as indicated in the last three paragraphs, keeping in mind, however, that only the cubic volume of the boles is thus obtainable. The branch-wood-percentage or the timber-percentage of the bole must be estimated.

The Hartig method (Paragraph XLVI.) might be combined with the use of Pressler's telescope, and the bole volume of a wood above breast height might be ascertained as 2/3 of the total sectional area of the forest, multiplied by the arithmetical mean of the rectified heights of the sample trees representing the various diameter classes.

$$V = \frac{2}{3} \times \frac{S\,(r_1 + r_2 + r_3 + r_4 + r_5)}{5}$$

The bole volume below breast height in cubic feet is equal to the sectional area of the wood times 4½.

PARAGRAPH XLIX.

COMBINED MEASURING AND ESTIMATING.

If measuring and estimating are combined, the following typical methods may be used to ascertain the volume of woods:

1. The form factor method (Paragraph L.).
2. The form height method (Paragraph LI.).
3. The volume table method (Paragraph LII.).
4. The yield table method (Paragraph LIII.).

These methods might be used in connection with the so-called "distance figure" of Paragraph LIV.

In applying these methods, one or the other of the three factors of volume (sectional area, height and form factor) are obtained by estimation.

The paragraphs following Paragraph LVIII. give a number of methods practically used and also based on combined measuring and estimating.

PARAGRAPH L.

FORM FACTOR METHOD.

The form factor method ascertains the sectional area by calipering, according to species, and, if necessary, according to height classes. The average height of the wood (by species, classes) is obtained by actual hypsometric measurement. The form factor is read from local form factor tables.

The average height is obtained—not as the arithmetic mean of a number of heights measured, but much more—correctly from the ratio existing between the sum total of the ideal cylinders and the sum total of the sectional areas of the trees hypsometrically measured. The form factors appearing in form factor tables must be averages obtained by many hundreds of local measurements.

Mistakes amounting to up to 25% in the sum total of the volume obtained by the form factor method are not impossible, since average form factors appearing from a form factor table are often at variance with the actual form factor.

Form factor tables for American "second growth" are still lacking. In primeval woods the form factor method seems out of place.

PARAGRAPH LI.

FORM HEIGHT METHOD.

The form heights of merchantable trees are, generally speaking, subject to only small variations. Those, *e. g.*, for Adirondack White Pine scaling from 18″ to 36″ in diameter breast-high are (for standard rule) close to 1.25.

Multiplying the sectional area of a White Pine woodlot (say 100 square feet) by the form height previously obtained through official measurements (like those by T. H. Sherrard), the volume of the woodlot—in the present example about 125 standards—is easily obtained.

Form height tables based on feet b. m., Doyle, are not as simple as those based on the standard rules and cubic foot rules, owing to the mathematical inaccurary of Doyle's rule, which causes the form heights to be pre-eminently dependent on the diameters.

Form height tables should be constructed for the leading merchantable species in the United States. Of course, such tables are more readily applicable to second growth than to first growth.

The form height tables should exhibit the number of standards, cords, ties, etc., obtainable per square foot of sectional area in each diameter class. In case of defective trees, proper allowance must be made for defects—rather a hazardous risk in primeval hardwoods.

PARAGRAPH LII.

VOLUME TABLE METHOD.

In Paragraph XXXVIII. a number of volume tables have been enumerated, from which the volume of trees of given species and diameter (and height) can be readily read.

A valuation survey of the forest (or of a woodlot or of a sample plot) yields the diameters of the trees stocking thereon. The number of trees found for each diameter class is multiplied by the contents of a tree of that diameter appearing from the volume table. The sum total of the multiples is the sum total of the volume of the forest.

SAMPLE.

Diameter.	Yellow Pine.			Hickory.			Oak.		
	No. trees.	Average volume.	Total volume.	No. trees.	Average volume.	Total volume.	No. trees.	Average volume.	Total volume.
12	30	60	1.800	7	140	980	14	160	1.400
15	42	120	5.040	9	240	2160	5	200	1.000
18	17	300	5.100	18	370	6600	23	350	8.050
21	36	520	18.720	5	500	2500	22	520	11.440
24	33	780	25.740	12	660	7920	22	730	16.060
27	20	1080	21.600	6	840	5040	7	940	6.580
30	10	1420	14.200	3	1050	3150	10	1150	11.500
33	1	1800	1.800	....	....	....	5	1400	7.000
36	1	2200	2.200	....	....	....	5	1800	9.000
Totals.			96.200			28.350			72.030

Grand total.................................196.580′ B. M.

The volumes of the column "Average Volume" are taken from tables published by the Bureau of Forestry.

PARAGRAPH LIII.

YIELD TABLE METHOD.

All over Europe local yield tables are used to quickly ascertain the volume of pure, sound, even aged woods. For America, such yield tables —normal local yield tables—exist only in the white pine tables given in Pinchot and Graves' pamphlet, "The White Pine."

The method of construction of yield tables appears from Paragraph XCII. and following.

Under yield tables are understood "acre-volume-tables," whilst under volume tables are understood "tree-yield-tables."

Normal yield tables specify the age of even aged and pure woods, the height of such woods and the volume (by assortment) of such woods, according to the productiveness of the soil. An indication for the latter is found in the height growth.

Such yield tables hold good only for woodlots normally stocked. A woodlot is normally stocked "when all local factors of wood production have pronounced themselves unhampered in the annual production of fibre." Normal woods, even of small extent, are extremely rare. In Germany the average wood lacks 25% of being normal. Since the normal yield tables give the yield for normal conditions only, a deduction must be made from the volume indicated by the yield table when applied to a given woodlot, according to the abnormality of the same.

Proceed as follows:

Ascertain age and average height of the trees; find the yield table which gives a similar height for the same age; reduce the volume indicated by this yield table and for this age, by estimating the deficiency of the growing stock.

Obviously, there is much room for guessing, since neither height nor form figure nor sectional area in woodlots abnormally stocked can lay claim to normality.

Schuberg, denying a truism otherwise generally acknowledged, claims that the height alone does not indicate the productiveness of the soil.

At present, normal yield tables are of little use in American forestry.

PARAGRAPH LIV.

DISTANCE FIGURE.

Under "distance figure," an invention of Kœnig's, is understood the quotient *a* formed by the side *l* of the average growing space of a tree (considered as a square) and by the diameter of the average stem *d*.

$$a = \frac{l}{d}$$

The average distance from tree to tree and the average diameter of a number of trees is obtained by a number of measurements in the forest. If the area of the forest is *F* square feet, then the sectional area of the forest is

$$= \frac{\pi}{4} \times \frac{F}{a^2} \text{ square feet}$$

The actual test proves the fallacy of Kœnig's assumptions. The explanation lies in the fact that the average diameter of a wood is not the arithmetical mean of the diameters composing it. Further, the growing space of a tree is not a square.

The actual growing space per tree can be correctly ascertained by laying a sample strip through the forest, counting at the same time the trees within the strip. The sectional area of the forest is obtainable, however, without greater trouble and with much greater accuracy, from the product calipered sectional area of trees in the sample strip times area of the forest over area of the sample strip.

On an acre of average soil, there is on an average room for the following numbers of healthy trees, according to age:

At 20 years 1,600 specimens.
At 50 years 600 specimens.
At 100 years 240 specimens.
At 150 years 150 specimens.

PARAGRAPH LV.

ALGON'S UNIVERSAL VOLUME TABLES.

So-called "universal volume tables" have been constructed by H. Algon, a Frenchman. For a description of these tables see "Indian Forester" of July, 1902.

The volumes given for each diameter of trees, whatever the species be, are presented on a number of tables as follows:

Diameter.	Volume in Cubic Feet.				
	Table 1.	Table 5.	Table 10.	Table 15.	Table 20.
6″	2.	3.	4.	6.	8.
9″	5.	8.	10.	16.	18.
12″	9.	15.	21.	27.	33.
15″	19.	28.	39.	50.	61.
18″	27.	39.	59.	69.	84.
21″	43.	60.	83.	109.	128.
24″	54.	78.	108.	138.	168.
27″	72.	107.	147.	188.	228.
30″	87.	129.	177.	228.	276.
33″	111.	163.	221.	288.	349.
36″	129.	189.	258.	333.	405.

The tables are used as follows:

1. Caliper the entire forest according to diameters and species.

2. Measure a number of type trees, selected at random, after felling them.

3. Find that volume table amongst the 20 tables given which best corresponds with the diameters and volumes of the type trees. Apply the volume table, which is found to be the proper one, to all diameter classes calipered in the woods.

Objections to the method are:

a. The danger of mistakes is very great. In an absolutely even aged wood, one tree of 15 inches diameter may easily show 50% more volume than another tree of the same diameter, the latter being more tapering and shorter.

b. In an uneven aged wood the tables are necessarily wrong because the form height is a function of age as well as of height and diameter.

c. The method does not give any idea of the proportion of logs, fuel, bark, etc.

Algon calls these tables "universal" assuming that they hold good for all species of the universe.

PARAGRAPH LVI.

SCHENCK'S GRAPHIC METHOD.

This method, as well, can be used only for sound woods. No calculation is required. The procedure is:

1. Caliper the whole wood.
2. Cut sample or type trees of small, big and average diameters, find the contents of each tree separately, together with the composition of contents as logs, fuel and bark.
3. On a piece of cross section paper, use as many units along a horizontal line as there are trees (or tens or hundreds of trees) calipered.
4. Mark the unit which each sample tree, according to its diameter, would occupy if the biggest tree were placed to the right and the smallest to the left of the horizontal line.
5. Enter over the marked units the volume of the type trees (according to the composing factors, if required) in square units. A square unit might correspond with ten feet board measure, or with 1/100 of a cord, etc.
6. Draw a line joining the ends of the columns, adjusting it by an average curve.
7. Measure the space (in square units) between the curve and the horizontal line with the help of a planimeter; the number of square units giving directly the number of feet Doyle, or of cords, etc.

If there are several assortments of volumes, several curves must be drawn. This method allows of separating the volumes of trees allotted to the several diameter classes. Mathematical errors are, practically, excluded.

PARAGRAPH LVII.

FACTORS GOVERNING THE SELECTION OF A METHOD OF VALUATION SURVEY.

In the case of a valuation survey ("stock taking") in the woods, the following points must be considered:

a. The degree of exactness required, which depends on the purpose at stake (*e. g.*, scientific investigations, or preparation for logging, or taxation).

b. The regularity, uniformity and soundness of the growing stock.

c. The minimum diameter of logs; assortments; marketability of species.

d. The possibility of cutting sample trees.

e. The expense permissible.

The question usually arises whether the entire forest or sample plots only must be surveyed. The answer depends on the configuration of the ground, uniformity of the growing stock as to size, age, species and quality of its components; further on the value of stumpage, on the accuracy required, on the available time and on the available funds.

The following *METHODS OF VALUATION SURVEYS* might be distinguished:

I. *Cutting sample trees.*

a. Sample trees selected for about five diameter classes, each class containing about one-fifth of the number of trees present (Draudt-Urich method).

b. Sample trees selected for about five diameter classes, each class containing about one-fifth of the sectional area of all trees present (Robert Hartig method).

c. Sample trees selected as average-diameter-trees of the entire forest (Old Bureau method).

d. Sample trees selected at random—*e. g.*, from dead and down trees (C. A. S. method—applied in the Balsams; Algon Universal tables; Graphic method).

e. Stem analysis, together with investigations as to thickness of bark.

II. *Without cutting sample trees.*

a. Measuring height and diameter and estimating form figure of sample trees.

b. Measuring rectified heights and diameters.

c. Measuring merely diameters and estimating form heights.

d. Photographing sample trees, having a scale—say a stick 6 feet long—on the picture.

III. *With the help of volume tables.*

IV. *With the help of yield tables.*

PARAGRAPH LVIII.

FACTORS INFLUENCING THE SELECTION OF SAMPLE PLOTS.

If sample plots are taken, there must be determined:

a. The number, situation and distribution of the sample plots.

b. The absolute and relative size of the sample plots. The Bureau of Forestry prescribes sample plots equalling from 1 to 4½% of the forest. The "Forest Reserve Manual" prescribes 5% or more.

c. The form of the sample plots and the manner by which the size of the sample plot is ascertained.

In Europe an ordinary workman calipers, on an average, 5,000 trees (in maximo 12,000 trees) per day. In Pisgah Forest 500 trees is a good day's work for one estimator and one helper.

PARAGRAPH LIX.

SIR DIETRICH BRANDIS' METHOD.

The Brandis method is indicated where the object at stake consists in a rapid survey of the stumpage on large tracts, like the vast Teak and Bamboo forests of upper Burmah.

Traversing existing trails of known length on horseback, the estimator records the diameter of each tree within a given distance (say 200 yards) on either side of the trail.

The widths of the strips traversed multiplied by the length of the trail yields the area of the sample plot. The number of the trees of the various diameters found on the sample strip appears from the records.

PARAGRAPH LX.

PINCHOT-GRAVES METHOD ADOPTED ON DR. WEBB'S ESTATE.

1. Sample acres, measuring 4 x 40 poles, are irregularly laid into swamps, hardwood slopes and spruce slopes. The sum total of the sample acres is 3½% of the total acreage.

2. The length of a sample acre is actually chained off, whilst the width is ascertained (two poles to the left and two poles to the right of the chain) by tape, by pacing and by estimating.

3. The sites of the sample acres are not marked on maps.

4. All trees on the sample acres are calipered; a number of heights are taken on each sample acre; for each sample acre the average diameter, the average height and the number of trees are ascertained.

5. From these averages is deduced, for all sample acres, the average diameter, the average height and the number of trees. All these data, of course, must be given for the various species separately.

6. From volume tables previously constructed the volume of the trees having average height and average diameter is obtained and is multiplied by the average number of trees.

7. This multiplication yields the volume of the average sample acre.

Objections to this method of valuation survey are:

a. The tree of average diameter has neither average volume nor average height.

b. The average diameter should be obtained from the fraction "total sectional area over number of trees." It cannot be obtained correctly from the fraction "sum total of diameters over number of trees." Similar objections hold good for average height.

c. Guessing at the width of a strip, in dense growth, is rather risky.

Remark: Bulletin 36, page 125, states that volumes are now computed by the Bureau either by averaging the volumes found for the sample acres, thus obtaining the volume of a model acre as

$$\frac{v_1 + v_2 + v_3 + \dots\dots + v_n}{n}$$

(wherein *n* equals the number of sample acres); or by summing up all trees of each diameter class, by dividing each sum by the number of sample acres, and by thus finding for a model acre the average number of trees for each diameter class. In both cases the volumes for each diameter class are read from volume tables.

Allowance for defects is made according to local experience, all trees being calipered as if they were sound.

PARAGRAPH LXI.

THE GRIDIRONING METHOD.

1. Work with compass (if a topographical map is required, also with barometer or clinometer) and with several tapes or ropes. These ropes are meant to denote the sides of a strip; within the strip the sectional areas are taken with calipers or Biltmore sticks.

2. The tapes move continuously with the caliper men, and there is no stopping. The compass man keeps ahead of the measuring crew. One of the outside "tapers" has the correct length desired for a section. His tape must be run straight. The inner tapes may make snake lines. The tally man uses a fresh tally sheet for each section.

3. All strips lie parallel and are equidistant. The width of the strips depends on the density of growth, smallest diameter calipered, available help and accuracy required.

4. The distance between two parallel strips depends upon accuracy required, width of strip and variety of configurations.

5. Each strip is divided into sections of equal length. The tally sheet gives for each section the diameters (with bark) of the trees in that section; further, remarks on the run and altitudes of ridges and creeks traversed, on roads, settlements, existing surveyor's marks, forest fires, forest pasture, previous lumbering and regeneration. The number of seedlings in a section might be approximately given under the same head.

REPORT ON , bgg at for C. A. SCHENCK & CO., Biltmore, N. C.

	Strip.........				Sectio n No...			.....feet long				Grade							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
6																			
9																			
12																			
15																			
18																			
21																			
24																			
27																			
30																			
33																			
36																			
39																			
42																			
45																			
48																			

Compass Course:

Farms: whose
Reached at..................ft.

Trail or road. g. m. b.
Called
Reached at..................ft.

Creek..................ft. wide
Called
Reached at............. ....ft.

Ridge, sharp, flat
Called
Reached at................. ft.

Few, some, many seedlings of................
Few, some, many saplings of.................
Few, some, many poles of....................
Few, some, many fireshoots of ....

Ending at:

Advantages of the gridironing method are:

a. A topographical map is obtained at a slight extra expense. The original survey is controlled and the area of the tract is re-ascertained.

b. Cruisers are forced to traverse all sorts of country and are not allowed to skip swamps, cliffs, etc.

c. The proportion of flats, ridges, slopes, swamps, farms, or farm soil, pastures, etc., is found at the same time.

d. The strips may be used as permanent statistical sample plots, if they start from definite points (corners) and run in definite directions.

e. The procession of the cruisers is uninterrupted by stops; hence no loss of time.

For a picture of a convenient tally sheet holder see Graves' Handbook, page 123.

The gridironing method has been adopted by the working plan division in a somewhat altered form as follows (Bulletin 36, page 120):

1. Strips are always one chain (66 feet) wide. A section invariably comprises one acre equaling 1 x 10 chains.

2. The measuring tape is trailing in the center of a strip; two caliper men (proceeding one at the left, the other at the right hand of the tape) caliper a belt one-half chain wide, estimating the width at either side of the central tape.

3. The compass man or tally man with the front end of the tape attached to his belt goes ahead and stops at the end of every chain, allowing the calipers to catch up.

4. Thus there are ten stops for every acre; after 10 chains the tally man enters general notes.

5. Heights may be measured by a separate crew.

A crew of four men calipers in merchantable timber 20 to 40 acres per day; in small and merchantable timber from 15 to 25 acres per day; in longleaf pine up to 65 acres per day.

PARAGRAPH LXII.

FOREST RESERVE METHODS.

Roth's Forest Reserve Manual gives three methods of valuation survey, No. 1 and No. 2 being sample-area-methods, and No. 3 an entire-area-method.

1. Sample circles with a radius of 20 yards, the circle containing ¼ acre; the radius is estimated, or paced from a central stick. Two sub-methods are permitted, namely:

a. Count the number of trees of merchantable size; estimate the average tree according to log length, taper and thickness of bark; estimate the percentage of defectiveness (from 10% to 40% after Manual, page 49).

b. Caliper the trees in the circle into two-inch classes; estimate the average tree for each class and allow for defects as before.

In both cases a map must show the site of the sample circles. The circle method is not allowed in scattering timber. At least 5% of the entire area must be sample-circled.

2. Sample strips. Strips should be four rods wide, should run across ridges, should be shown on a map. Otherwise proceed as under 1.

3. The "forty" method is used on surveyed land. It is an entire-area method applied to 40 acres. The sides of a "forty" are 80 x 80 rods, equal to 440 x 440 yards. Prescriptions:

a. Traverse each "forty" on lines about 100 yards apart, thus crossing 4 times.

b. Halt at every 100 yards and estimate the trees within a square of 100 yards surrounding the stopping place.

c. If possible, have a compass man control the length and the direction of your runs.

PARAGRAPH LXIII.

SAMPLE SQUARES.

Sample squares containing about one acre are used in Maine and in Northern New York. The side of a sample square is 14 rods. A cruiser, from the center of the square, under the density of the growth existing in Maine and New York, can overlook a circle of 7 poles radius surrounding him. Hence, as a matter of fact—or rather of theory—he skips the corners of the square, counting only the trees in a circle which has the side of the square for its diameter. The square contains 196 square rods, whereas the circle of 7 poles radius contains 155 square rods. The cruiser estimates the contents of all trees within the "square" from his central standpoint.

PARAGRAPH LXIV.

PISGAH FOREST METHOD OF 1896.

1. The diameters of all trees promising to yield a log are measured in diameter classes of ½ foot interval by a crew of 4 to 5 helpers armed with Biltmore sticks.

The diameters are measured (or often estimated if beyond reach) at the point above which the tree is supposed to be sound.

2. Each tree measured is marked by a blaze. The foreman enters on a tally sheet the species and the diameters called out by the helpers. A special tally sheet is used for each cove.

3. The average contents of the diameter classes are estimated with the help of sample trees selected for each species and each diameter—a very uncertain estimate owing to the unsoundness of the trees.

4. Each cove is numbered or lettered to correspond with the tally sheet on a tree standing at the outlet of the cove.

PARAGRAPH LXV.

PISGAH FOREST METHOD FOR STUMPAGE SALE, BARK SALE AND LUMBERING OPERATIONS.

1. Each tree is approached individually, its diameter measured and its defects, especially its hollowness, examined by "sounding." The diameter measure and the estimated volume are entered on a tally sheet opposite the number of the tree, which is inserted in the stump of the tree by a stroke of the "revolving numbering hammer."

2. One cruiser and one helper tally 400 trees per day.

3. The method allows of ready control by the owner, the forester and the buyer. It is adapted to hardwood forests in a rough mountainous country where the merchantable trees per acre are few; and where no tree is, practically, free from defects. (Compare Graves' Bulletin No. 36, page 115).

PARAGRAPH LXVI.

HENRY GANNETT'S METHOD, ADOPTED FOR THE TWELFTH CENSUS.

1. Base the estimate on the cruising reports obtainable from the local lumber companies and railroad companies.
2. Control the applicability of the estimates to huge tracts by traversing them and by overlooking them from a mountain top.

Mr. Gannett expects that mistakes made in one county will be offset by those made in another.

PARAGRAPH LXVII.

A "FORTY" METHOD USED IN MICHIGAN.

1. A "forty" (a square of 80 x 80 poles) is subdivided into 10 rectangles of 4 acres each, measuring 16 x 40 rods.

2. The cruisers estimates when entering a rectangle. He counts the number of trees on every 4 acres and multiplies the number by the size of the average tree.

3. For each "forty" the cruiser records in a memorandum the factors influencing the logging operations or the timber values, notably the swamps, ridges, forest fires, degree of defectiveness, facilities of transportation.

A central line traversing the "forty" in a north and south direction is sometimes kept by a compassman assisting the cruiser. The outer lines of the "forty" are plain from the official survey marks.

A number of variations of this method exist, according to the custom of local cruisers and according to the predilections of the lumbermen, largely governed by the value of stumpage. Compare Graves' Bulletin 36, page 116.

PARAGRAPH LXVIII.

DR. FERNOW'S "FORTY" METHOD USED AT AXTON.

1. Each "forty" is subdivided into 16 squares of 2½ acres each, the sides of a square being 20 x 20 poles.

2. The head estimator, stepping from the corner of the square 10 poles east (or west) and 10 poles north (or south) places himself in the center of the square.

3. Helpers (students) are sent out, four in number, towards the northeast, northwest, southeast and southwest, each helper reporting the diameter and species of the trees found in that one-quarter of the 2½ acres which is allotted to him.

4. The "forties" are carefully surveyed and surrounded by carefully trimmed lines. The outlines of the 2½ acre sections are merely paced.

CHAPTER II.—AGE

PARAGRAPH LXIX.

AGE OF TREES CUT DOWN.

The age of trees cut down is found by counting the annual rings on a cross section (preferably an oblique cut) made as low above the ground as possible. Allowance must be made for the "stump years," by which is understood the number of years required by the top bud of the seedling, after sprouting, to reach the stump height ("cutting height," after Circular 445).

Ring-counting in the case of even-porous hardwoods requires the use of a lens and of some coloring liquid (aniline and ferro-chloride) on a disc planed with a knife, a chisel or a hollow planer.

The difference of the ring-numbers on the stump and the ring-numbers at any place higher up indicates the number of years used by the top bud of the tree to traverse the intervening distance. Endogenous trees do not form any rings.

False rings are formed under the influence of late frost, early frost, drought, fire and insect pests. They do not run all around the tree.

As long as the tree lives, it must annually form a ring of growth (or rather an additional coat, the sleeves of which cover the branches), the outside of which becomes a layer of bark, the inside of which is a layer of wood. In tropical countries this rule does not hold good provided that there is no change of season.

The formation of rings in the branches is regular. Branch-rings are, however, eccentric and elliptical. The formation of rings in the roots is said to be irregular, not representing the age of the root, possibly because there is no or little change of seasons in the soil.

PARAGRAPH LXX.

AGE OF STANDING TREES.

The age of standing trees can be estimated only when regular annual whorls of branches can be counted.

The records of seed years and the history of the forest kept by many forest administrations usually give an idea of the age of the trees.

PARAGRAPH LXXI.

AGE OF A FOREST.

The age of a forest is the average age of the trees composing it.

In the case of a thicket suppressed for a long time by the superstructure of a leaf canopy overhead, a so-called "economic age" is frequently substituted for the actual age. In the case of Adirondack spruce, for example, a diameter of 1 inch in the center of the trunk had better be counted, as, say, 15 years, although it may contain as many as 60 rings.

The mean age of an uneven-aged wood is defined as follows:

1. That number of years which an even-aged wood would require on the same soil, in order to produce the same volume as is now at hand.

2. That number of years which an even-aged wood would require in order to produce at the time of maturity the same volume which the uneven-aged wood is likely to produce.

The latter definition is scientifically more correct. Unless it is adopted, an uneven-aged wood may get over 20 years older in 20 years, owing to the fact that the trees dying in the meantime are mostly minors in age.

CHAPTER III.—INCREMENT

SECTION I.—INCREMENT OF A TREE.

PARAGRAPH LXXII.

THE KINDS OF INCREMENT.

The following kinds of increment must be distinguished:

a. Increment of height, diameter, sectional area and volume.

b. Current annual increment, current periodic increment and total increment.

c. Average annual increment, average periodic increment and average increment at the age of maturity.

d. Increment of the past and increment of the future.

e. Absolute increment and relative increment.

The increment of stems cut down is found by counting and measuring the annual rings on several cross sections.

The term "stem" or "tree analysis" designates an investigation into the past height growth, diameter growth and volume growth of a tree.

Circular 445 of the Bureau of Forestry defines the term "increment," somewhat narrowly, as follows: "The volume of wood produced by the growth in height and diameter of a tree or of a stand."

For definition of the term "tree analysis," see Circular 445 of Bureau of Forestry.

This circular distinguishes between:

1. Stump-analysis, being a tree analysis which includes measurements of the diameter growth at given periods on the stump only, no matter what other measurements it may comprise;
2. Section-analysis, being a tree analysis which includes measurements of the diameter growth at given periods upon more than one section of a tree;
3. Partial tree (stump or section) analysis, wherein the measurement of the diameter growth at given periods covers a portion only of the total diameter growth.

PARAGRAPH LXXIII.

HEIGHT INCREMENT.

The height increment, from the silvicultural standpoint, is of interest to the forester dealing with mixed woods.

The difference between the number of rings found on two separate cross sections through the bole indicates the number of years which the tree has required to grow through the distance lying between these two sections. By counting the number of rings at several cross sections, one of which is made as close to the ground as possible, the current and the average height growth (increment) may be obtained by arithmetical or by graphical interpolation.

A dense cover favors height increment. In rare instances, however, the stand of saplings or poles is so close that the height increment of the individual suffers from lack of food.

PARAGRAPH LXXIV.

THE CURRENT HEIGHT INCREMENT.

In the high forest the current annual height increment reaches a maximum at an early age; passing this maximum, it sinks more or less rapidly. The culmination of the current annual height increment occurs the much earlier and its slackening after said culmination goes on at a more rapid rate if

1. the species is fast growing and light demanding;
2. the tree observed belongs to the dominant class;
3. the soil is good.

For yellow pine the culmination of the current annual height increment occurs amongst dominant saplings between the 10th and 15th years; for spruce at about the 20th year; for beech and fir between the 25th and 30th years. Suppressed trees show the maximum of current height growth much later than dominant trees.

As a general rule for all species, in case of dominant trees, the longest shoot is made 10 to 15 feet above ground. Slow growing species, shade bearers and trees stocking on poor soil reach that level at a later date than trees and species growing under reversed conditions.

In the case of coppice forest, the maximum of the current height growth lies in the first three years of the life of the shoot. For oak coppice, the following table may serve as an illustration of height growth:

Growth in Feet.

Age in years	10	20	30	40	50
Actual height	13′	23′	30′	37′	43′
Current annual increment	1.3′	1.0′	0.7′	0.65′	0.63′

PARAGRAPH LXXV.

THE AVERAGE HEIGHT INCREMENT.

The average annual height increment culminates later than the current annual height increment, and, after the culmination, it decreases at a less rapid rate than the current annual height increment. The average annual height increment culminates at the very age at which it is equal to the current annual height increment.

As long as the average increment increases the current increment is larger than the average. The average increment still rises during a period of decrease of current increment.

These laws hold good not only for height growth, but also for the growth of diameter, sectional area and volume. They are based merely on mathematical principles and are, for that reason, independent of species, climate and soil.

If "a" denotes the current annual increment, and if "d" denotes the average annual increment, whilst the indices 1, 2, 3, etc. (up to *n*), indicate the year of increment, then the following five equations hold good:

$$n \times d_n = a_1 + a_2 + a_3 \ldots\ldots + a_n$$

$$(n + 1)\, d_{n+1} = a_1 + a_2 + a_3 \ldots\ldots a_n + a_{n+1}$$

$$(n + 1)\, d_{n+1} = n \times d_n + a_{n+1}$$

$$n \times d_{n+1} = n \times d_n + a_{n+1} - d_{n+1}$$

$$n\,(d_{n+1} - d_n) = a_{n+1} - d_{n+1}$$

PARAGRAPH LXXVI.

RELATIVE INCREMENT OF THE HEIGHT.

The percentage of height increment forms, from the start on, an irregularly descending progression.

If the height is *h* at the beginning of a period of *n* years of observation and *H* at the end of that period, then

$$h \times 1.\,op^n \text{ equals } H$$

and

$$p \text{ equals } 100\sqrt[n]{\frac{H}{h}} - 100$$

Pressler substitutes for this formula in case of short periods of observation the following:

$$p = \frac{200}{n} \times \frac{H - h}{H + h}$$

This formula is derived as follows: Imagine that we are in the midst of the period of *n* years. At that time, the increment is apt to be $\frac{H - h}{n}$, whilst the height at that time is apt to be $\frac{H + h}{2}$; hence, for that middle year, the equation is:

$$\frac{p}{100} = \frac{H - h}{n} \times \frac{2}{H + h}$$

PARAGRAPH LXXVII.

DIAMETER INCREMENT.

The current diameter increment is obtained by counting and measuring the rings on a disk through the tree. It is generally best to count from the bark towards the center, along two radii standing perpendicular to each other.

The general laws of diameter growth are identical with those of height growth relative to culmination, decrease and increase of absolute (Paragraph LXXV.) as well as of relative (Paragraph LXXVI.) increment.

If we exclude the butt-piece below chest-height, the annual rings along the tree bole measured at various elevations above ground show a gradual increase of width with elevation, provided that the leaf canopy of the forest is complete and uninterrupted—*e. g.*, the width of the ring 50 feet from the ground, formed in 1903, is greater than the width of the ring formed 20 feet above ground in the same year.

For trees standing in open crown-density, the width of the ring decreases with the elevation above the ground, especially within the crown itself.

A tree standing in a thin crown-density may show an even width of ring all over the tree bole.

For very old trees in closed stand it is sometimes found that the diameter, say 40 feet above ground, is larger than the diameter, say, 20 feet above ground.

The rings on a disk are not actually circles; they more closely approach the form of eccentric ellipses (see Paragraph XIII.).

PARAGRAPH LXXVIII.

SECTIONAL AREA INCREMENT.

The increment of the sectional area is obtained from the increment of the diameters. Where greater exactness is required, and especially in case of irregular rings, the planimeter or the weight of a piece of paper having the form of the sectional area may be used for measuring to good advantage (Paragraph XIII.).

The increment of the sectional area at chest height depends on the crown density overhead; further, on the quality of the soil. At chest height the culmination of the current annual sectional area increment takes place, in the case of dominant trees, fast growing species and complete cover overhead, between the years 40 and 70.

The culmination of the current annual sectional area increment occurs always later than the culmination of the current height and diameter increment. After culmination it remains uniform for a long time.

The absolute increment of a sectional area higher up on the bole, compared with the absolute increment at chest height, is found to be equal to it in the case of dominant trees; larger in the case of suppressed trees; and smaller in the case of isolated trees.

Pressler establishes as the "law of bole formation" the following rule: "The absolute increment of the sectional area at any point of a bole is directly proportioned to the leaf surface above that point."

This rule is, on the whole, correct. An unexpected swelling, however, is often found at 9/16 of the height of the tree. Within the crown of the tree, the decrease of sectional area increment is rapid.

PARAGRAPH LXXIX.

RELATIVE INCREMENT OF DIAMETER AND OF SECTIONAL AREA.

The increment percentage at any point of the bole, like all increment percentages, forms a constantly but irregularly descending progression.

At any point of the bole the increment percentage of the sectional area is the double of the increment percentage of the diameter.

Schneider gives a handy formula for the sectional area increment percentage, viz.:

$$P \text{ equals } \frac{400}{nd}$$

wherein d represents the diameter at the beginning of the period of observation, and wherein n indicates the number of rings per inch at the time of observation.

The percentage of the sectional area increment increase along the bole with increasing height of the disk measured, excepting, however, possibly, the case of very isolated trees.

The average sectional area increment percentage of the bole is found at a point a little below one-half of the total height, namely, at about 0.45 of the total height from ground.

PARAGRAPH LXXX.

VOLUME INCREMENT.

The (current and future) volume increment of standing trees is of great interest to forest financiers; it can be estimated only, and cannot be measured exactly.

The volume increment of trees cut down may be ascertained as follows:

1. By the sectional method, or by "section analysis" (Paragraph LXXXI.).

2. From the increment of sectional area chest high, height increment and form figures (Paragraph LXXXIV.).

3. From the increment of sectional area in the midst of bole (Paragraph LXXXV.).

4. On the basis of the average annual increment (Paragraph LXXXVII., last 4 lines).

PARAGRAPH LXXXI.

SECTION ANALYSIS.

The section-method is a complete tree analysis by sections. The entire bole is divided into a number of sections, preferably of even length, at both ends, or, better, in the midst of which the periodical increment of the sectional area is ascertained (compare Paragraph XI.).

In the latter case, multiplying such sectional areas (in square feet) as belong to the same age of the tree by the length (in feet) of the sections, the volumes (in cubic feet) of the different sections at given ages are obtained.

The "top pieces," however, must be figured out separately, their length differing from the even length of the sections. These top pieces are usually considered as cones, and their volumes are ascertained as one-third height times basal area of top piece. The basal area of the top piece is identical with the upper area of the uppermost full section of a given age.

EXAMPLE FOR HUBER-SECTIONS TEN FEET LONG.

Total height....................	25 feet.	40 feet.	67 feet.
Total age......................	20 years.	40 years.	60 years.
Sectional area of Section 1	0.34 sq. ft.	0.78 sq. ft.	1.23 sq. ft.
Sectional area of Section 2........	0.15 sq. ft.	0.45 sq. ft.	0.87 sq. ft.
Sectional area of Section 3........	....	0.25 sq. ft.	0. 64 sq. ft.
Sectional area of Section 4........	....	0.03 sq. ft.	0.53 sq. ft.
Sectional area of Section 5........	....	....	0.25 sq. ft.
Sectional area of Section 6........	....	....	0.04 sq. ft.
Summary of sectional areas......	0.49 sq. ft.	1.51 sq. ft.	3.56 sq. ft.
Summary sectional areas x 10.....	4.90 cu. ft.	15.10 cu. ft.	35.60 cu. ft.
Volume of top piece.............	0.05 cu. ft.	0.09 cu. ft.	0.08 cu. ft.
Total volume..................	4.95 cu. ft.	15.19 cu. ft.	35.68 cu. ft.

The volume of the top pieces forms in the older age columns an insignificant part of the total volume.

If the logs as cut in the woods are used as sections, then each section has a separate length and its volume must be separately ascertained for every decade of age of tree.

REMARK: It is wise to first ascertain the full age of the tree, allowing for stump years. It is further wise to throw off that number of years which exceeds full decades—*e. g.*, in case of a tree 117 years old, 7 years.

At the stump the rings had best be counted from the inside out, allowing for stump years. Instance: Age of tree, 117; stump years, 4 years; counting on the stump, from the inside, 6 rings establishes the ring formed in the year 10. Continuing, the rings of the years 20, 30, 40, 50, etc., up to year 110, are pencil marked. The outside seven rings are thrown off.

At all other disk-sections, count and measure from the outside in, after discarding the 7 years exceeding full decades of tree life.

PARAGRAPH LXXXII.

NOERDLINGER'S PAPER WEIGHT METHOD.

The total length of the tree is divided into 8 Huber sections, and cuts are made in the midst of these sections, at the height of 1/16, 3/16, 5/16, 7/16 and up to 15/16 of the bole. On each cross section the radii are measured, not with the rule, but with dividers.

On a piece of paper folded 4 times and thus divided into 8 sectors the measurements are entered with the help of the dividers, one sector being allotted to the first cross section, the next sector to the next cross section, etc. Multiplying the total weight of the zone indicating, say, the year 70, by height of the tree and dividing the product by the weight of a square foot of paper, the volume of the tree when 70 years old is directly obtained in cubic feet. Similarly the zones corresponding with the year 50, 60, etc., are cut out, weighed and multiplied.

If the volume increment percentage p alone is to be obtained, then it is enough to divide, say, the "weight" of the year 70 by the weight of the year 60, and the 10th root of the quotient will equal 1.0p.

PARAGRAPH LXXXIII.

SCHENCK'S GRAPHIC TREE ANALYSIS.

Graphic tree analysis offers the following advantages:

1. Mistakes are impossible, being at once noticeable on the diagram paper.

2. The volume in feet Doyle can be readily obtained for any stated minimum diameter.

3. The graphical sketch is adaptable to any of the 43 scales in use in the United States, as well as to the metric system.

4. The thickness of heart wood and sap wood and bark readily appears.

5. It is immaterial whether measurements are taken in meters or in feet, the graphical sketch readily allowing of transfers into other units.

6. Height growth and diameter growth appear at the same time, and from the same entries.

7. The length of the sections taken need not be uniform.

The method of proceeding is as follows: On millimeter paper a system of co-ordinates is established; heights are entered as ordinates, diameters or radii as abscissas. The scale for the height entries should be much smaller than that of the diameter entries.

Diameter points, at the different section-heights, corresponding to a given decade of years are joined (beginning at the outside), by which procedure the outline of the tree at that decade is established.

Th top cones are obtained by prolonging such outlines arbitrarily until they intersect with the height-axis.

The merchantable bole for each decade is dissected, on the diagram, into logs the length and diameter of which are measured on the diagram.

PARAGRAPH LXXXIV.

WAGENER'S METHOD AND STUMP ANALYSIS.

Wagener recommends a partial stem analysis for cases in which a knowledge of the absolute increment, not a knowledge of the absolute tree volume, is required. Tree volume is sectional area chest high times height of tree times form factor.

Wagener analyses:

a. the height growth by counting the rings at various altitudes along the bole;

b. the growth of the sectional area at chest height by measurement in decades in the usual way.

Wagener then estimates the form factor according to form factor tables.

In the latter proposition, obviously, lies the danger of mistakes. Since, however, increment is a difference of volumes, merely the difference of mistakes—a comparatively small item—enters into the problem.

Age in years	60	80	100	120
Diameter b. h.	14.	17.	19.	21.
Sectional area b. h.	0.25	0.35	0.50	0.71
Height in feet	75.	85.	93.	105.
Form factor	0.50	0.50	0.50	0.50
Volume in cubic feet	9.4	13.	23.	36.
Increment in cubic feet	3.6	10.	13.	

The "stump analysis" (compare Paragraph LXXII.) introduced by the Bureau of Forestry rests on premises similar to those proffered by Wagener.

If the form height for the stump-diameters (or the number of feet b. m. per square foot of stump area for given stump diameters) is known, the rate of volume increment can be quickly ascertained by mere stump analysis.

It is, however, a well known fact that the diameter growth at the stump—especially at a low stump—is particularly unreliable as an index of volume growth, owing to the exaggerating influence on stump growth exercised by light, by water, by depth of soil and by superficial roots.

Stump analysis as a means to bring a volume in reference to a sectional area at the stump is permissible only as a necessary evil.

PARAGRAPH LXXXV.

PRESSLER'S METHOD.

Frequently the task before the forester is merely that of ascertaining the increase of bole volume during the last 10 or 20 years. Then after Pressler, one single investigation into the growth of the sectional area is sufficient when made with the help of the accretion borer in the midst of the "decapitated" bole. The volume increment in cubic feet equals the sectional area increment in question multiplied by the height of the tree.

The bole is decapitated by that number of top shoots which have been formed during the period of observation. This operation corresponds very well with the usual practice of judging the bole increment percentage from the sectional area increment ascertained at 0.45 of height of tree.

Pressler measures the sectional area at the end of the period of observation too large, measuring it at too low a point. He multiplies this sectional area, however, by too small a height—namely, the decapitated height; thus a mistake made in the positive sense is apt to be eliminated by a mistake made in the negative sense.

The axe can be used to better advantage frequently than the accretion borer.

PARAGRAPH LXXXVI.

BREYMANN'S METHOD.

Breymann gives the following formula:

1. For the current annual volume increment T:

$$T = V\left(2\frac{\delta}{d} + \frac{\lambda}{l}\right)$$

wherein "δ" and "λ" denote the annual increase of diameter "d" and length "l" respectively.

2. For the corresponding increment percentage P:

$$P = 100\left(2\frac{\delta}{d} + \frac{\lambda}{l}\right)$$

It appears that for trees of old age and hence of little height growth the increment percentage is merely dependent on the diameter increase.

Breymann, however, neglects:

1. The change of form figure, during the period of observation;

2. A number of small factors which ought to be embraced in the formula.

For stopping height growth or for $\lambda = 0$, the term given for P can be easily reduced to the term given by Schneider for the sectional area increment percentage.

PARAGRAPH LXXXVII.

FACTORS INFLUENCING THE CUBIC VOLUME INCREMENT.

The culmination of the current annual volume increment takes place at a later year than the culmination of the sectional area increment at breast height. Naturally so, because with increasing age of a tree, its root system as well as the branch system, the feeders of the body, show continuous increase.

Big and long branches, of course, require a great deal of wood fibre to increase and maintain their own strength, like levers increased in length. Hence, from a certain size of branch on, all wood fibre produced by the branch is used up within the branch itself, for its own purposes, instead of being added as increment to the merchantable bole.

After Dr. Metzger, the crown of a tree yields the maximum of bole increment if its crown diameter is, and if the number of trees per acre are:

Quality of soil.	Diameter of crown, in feet.	No. of trees per acre.
Very good.	16.5	203
Good	14.7	256
Medium	12.7	343
Poor	9.3	640
Very poor	8.3	807

From the theoretical standpoint it seems wise, consequently, to force the lower branches of a tree to die, with the help of proper tension and friction within the leaf canopy, when they exceed a length of 8.25, 7.35, 6.35, 4.65 and 4.15 feet respectively (the halves of the diameters).

Metzger's investigations are interesting, but his conclusions seem to be too sweeping.

P. P. Pelton recommends the lopping of branches in order to shorten the length of the branch-levers.

The average annual volume increment of dominant and sound trees culminates at a very high age only, if ever, owing to the late culmination of the current annual average increment.

The volume increment percentage forms—as in all cases of increment—a steadily but irregularly decreasing progression. This percentage is invariably equal to or higher than the sectional area increment percentage at chest height.

Roughly speaking, the volume increment percentage amounts to from 1 to 1.75 times the sectional area (at chest height) increment percentage, or, as Pressler gives it, to from 2 to 3½ times the diameter (at chest height) increment percentage.

Crown covers part of bole	Height Growth.			
	Seemingly nil.	Medium.	Good.	Excellent.
½ or more.	2.33	2.67	3.00	3.17
⅓ to ¼.	2.50	2.83	3.17	3.33
Less than ¼.	2.67	3.00	3.33	....

Since the average volume increment of a tree is equal or closely equal to the current annual increment at a high age only, it is usually not permissible to substitute the average increment, which is easily ascertained, for the current annual increment.

PARAGRAPH LXXXVIII.

VOLUME-INCREMENT PERCENTAGE OF STANDING TREES.

In the case of standing trees the volume increment percentage cannot be measured, owing to the impossibility of ascertaining a change of form height.

The Pressler data given in the preceding paragraph allow of estimating the volume increment percentage of standing trees on the basis of a diameter-increase, measured at breast height.

The Pressler "accretion borer" is used for the purpose, or an axe.

Stoetzer, Director of the Forest Academy at Eisenach, modifies the Schneider formula for sectional area percentage, writing it

$$p = \frac{C}{nd}$$

wherein *n* indicates number of years (rings) required to form one inch; *d* represents the diameter at the beginning of the period of investigation, whilst *C* (the so-called "constant factor of increment," which is not a constant factor at all) must be ascertained for a given species, soil, diameter, age and position by actual tests on felled trees.

In old dense beech woods *C* is, e. g., 540. After a seed cutting in the same woods during the final stage of regeneration *C* is only 450 (observation by Dr. Wimmenauer).

Trees growing as cones would grow, have C equal to 600; trees growing as Apollonian paraboloids would grow, have C equal to 800; after Stoetzer, C might amount to as much as 930, in case of suppressed trees. The minimum possible (in sound trees) for C is 400.

The Pressler values given in the table of the preceding paragraph closely correspond with the constant factors of increment ascertained after Stoetzer. In the case of the Pressler table (at end of Paragraph LXXXVII.) we find, for medium height growth and very small crown, a factor 3.00 by which the diameter increment percentage is to be multiplied. This factor 3.00 corresponds with 600 for a constant factor of increment.

If the diameter in the midst of the bole is ½ of the diameter at the end, then the tree, it seems, is conical, and an increment factor of 600 might be assumed. If the sectional area in the midst of the bole equals ½ the sectional area at the end, then the tree is a paraboloid, and the increment factor seems apt to be 800.

It must be remembered, however, that a tree forming a paraboloid grows as a paraboloid only, if its percentage of height growth is equal to its percentage of growth of sectional area—a rare case in merchantable trees.

Similarly, a tree growing as a cone must have the height increment percentage equal to its diameter increment percentage.

If n and ν represent the number of rings per inch added to original diameters d and δ at chest height and at 0.45 of the height of the tree respectively, then the "constant factor of increment C" is found as follows:

$$\text{p (volume)} = \frac{400}{\nu\,\delta} = \frac{C}{nd}$$

$$C = 400\frac{nd}{\nu\,\delta}$$

PARAGRAPH LXXXIX.

INTERDEPENDENCE BETWEEN CUBIC INCREMENT AND INCREMENT IN FEET B. M. DOYLE.

Doyle's rule under-estimates the contents of small logs and over-estimates those of big logs.

Consequently, the growth of a tree bole in feet b. m. Doyle is (for small trees yielding logs under 28″ diameter) relatively faster than the growth of a tree bole expressed in cubic feet. The figures of Column D denote, in the following table, this excess rate of growth:

A Diameter of logs without bark.	*B* No. of ft. b. m. per one cu. ft. of timber estimated after Doyle.	*C* Differences of consecutive figures in Column B.	*D* "Extraordinary" percentage of increment Doyle co-inciding with 1" growth.
12"	5.09		8.1
		0.41	
13"	5.50		6.4
		0.35	
14"	5.85		5.7
		0.33	
15"	6.18		4.2
		0.26	
16"	6.44		4.3
		0.27	
17"	6.71		3.3
		0.22	
18"	6.93		2.1
		0.14	
19"	7.07		3.2
		0.26	
20"	7.33		2.5
		0.18	
21"	7.51		2.2
		0.16	
22"	7.67		2.0
		0.15	
23"	7.82		1.7
		0.13	
24"	7.95		1.8
		0.14	
25"	8.09		1.4
		0.11	
26"	8.20		1.5
		0.12	
27"	8.33		1.1
		0.09	
28"	8.41		1.1
		0.11	
29"	8.52		1.0
		0.08	
30"	8.60		...

For the standard rules, the increment percentage of a tree can be ascertained by cubic measure as well as by standard measure.

If *n* years are required to form one additional inch of diameter, then the extraordinary percentage of Doyle-increments amounts annually to $\sqrt[n]{1.0\,D}$, wherein D represents the values of Column D in the foregoing table.

By this factor $\sqrt[n]{1.0\,D}$, the cubic volume increment percentage of a bole may be converted, *ceteris paribus*, into Doyle increment percentage, provided that

1. The cubic increment percentage of the total bole coincides with the cubic increment percentage of the merchantable bole;

2. The merchantable bole does not increase in length during the period of observation.

PARAGRAPH XC.

CONSTRUCTION OF VOLUME TABLES.

Volume tables are "tree yield tables" from which the volume of a tree of given species, given age, given diameter breast high or stump high, given height, given merchantable bole, given position (suppressed, dominant, etc., or isolated, crowded, etc.), given locality and so on can be readily read. The units of volume are cubic feet, board feet, standards, cords, etc., according to the requirements of the case.

Obviously, volume tables give, or should give, the volumes of average trees; they may give, in addition, the maximum and minimum volume possible in a tree of stated description.

Volume tables are constructed either on the basis of hundreds (thousands) of measurements taken from trees actually felled in the woods (possibly also sawn at a saw mill, to ascertain the grades) or on the basis of a smaller number of complete section analyses.

The rapidity of volume growth of a species and the development of its form height depend on many local factors—notably on climate, soil, sylvicultural systems at hand, influence of fires, fungi, insects, etc.

Owing to the multitude of local factors influencing the volumes and the changes of volumes, local volume tables alone are entitled to a place in exact mensuration.

Volume tables for second growth are more reliable than volume tables for first growth.

Circular 445 of Bureau of Forestry defines volume table as "a tabular statement of the volume of trees in board feet or other units upon the basis of their diameter breast high, their diameter breast high *and* height, their age, or their age *and* height."

The method of construction of volume tables is either mathematical or graphical.

1. *Mathematical method.*

The volumes ascertained for trees of a given diameter (breast high or stump high with or without bark), a given merchantable length or total length, a given age or a given quality or locality are added up.

The sum total of these volumes divided by the number of trees forming it yields the average volume of the tree of stated description.

These averages are shown, for the various diameters, lengths, ages and localities, in tabular form.

The volumes corresponding with such diameters, lengths, ages and localities, for which sample trees were not cut and measured, are found by arithmetic interpolation.

Finally, the differences in volume shown by average trees of similar description (*i. e.,* differing but slightly in diameter, length, etc.) are formed and rounded off in a manner causing the volumes to show a more steady mathematic progression.

2. *Graphic method.*

The volume of each tree measured is entered as the abscissa on a diagram-system of co-ordinates, whilst the diameters of the trees (or the age, etc.) are registered on the ordinate axis. Similarity of length is indicated by color of mark representing the tree; similarity of locality is indicated by the form of the mark (square, triangle, cross, circle, etc.).

Corresponding marks are then joined by chains (having square, circular, triangular links) of the proper color.

Finally, average curves as well as maximum and minimum curves are drawn for the various colors and forms of marks.

Maximum and minimum curves should not represent the very best and the very worst possibilities; they should represent the average of very good and very bad trees.

The graphic method is more reliable, because less depending on mere figures, than the mathematical method. Both methods are frequently combined.

A number of complete tree analyses furnishes more reliable results than a large number of mere volume measurements because it yields more reliable curves (guide-curves) of development for one and the same locality, and because it prevents the forester from drawing curves of growth at random.

If the sample trees (or sample logs) are sawn up at a saw mill where the lumber is properly graded according to the inspection rules prevailing for the species in question, the volume tables may also give the actual average output of specified trees in lumber of the various grades.

SECTION II.—INCREMENT OF A WOOD.

PARAGRAPH XCI.

INCREMENT OF FORESTS.

The volume increment of the virgin forest is on the whole nill.

In America the value increment of a primeval forest is based more on a price increment of stumpage than on a volume increment of trees. The volume increment, in addition, can scarcely be ascertained with sufficient accuracy for a given piece of forest at a reasonable expense.

In second growth forests, on the other hand, say in Virginia, an absolute knowledge of the productiveness of the forest renders forestal investments safer in the eyes of the owner; and the safety of the investment it is which alone can tempt the capitalist to invest in forestry. A knowledge of the increment in second growth woodlands can be obtained from tabulated statements ("yield tables") showing the rate of growth for woodlands of a given species in a given locality. Under normal yield tables are understood such tables which give the rate of growth for even-eged, pure, normally stocked, well thinned woodlots for given localities (compare Paragraph LIII. and XCIV..).

Such normal yield tables are constructed abroad for beech, pine, spruce, fir and oak. In this country they exist only in Pinchot's and Graves' yield tables for white pine. In America, pure even-aged woods are found in rare cases only (taeda, echinata, rigida, jack and longleaf pines, tamarack, coppicewood).

In the construction of normal yield tables the following points require consideration:

1. The different methods of construction (Paragraph XCII.).

2. The combination, interpolation, adjustment and correction of the results (Paragraph XCIII.).

3. The contents and use of yield tables (Paragraph XCIV.).

PARAGRAPH XCII.

METHODS OF CONSTRUCTION OF NORMAL YIELD TABLES.

Normal yield tables may be based on:

A. Repeated survey of some typical woodlots during their entire lifetime.

B. Repeated survey of different woods standing on an equal quality of soil, during a period of years equal at least to the longest difference in age found amongst them.

C. One-time, simultaneous survey of a very large number of woods of different ages standing on different qualities of soil. Missing links are here obtained by graphic or mathematical interpolation (Paragraph XCIII.).

If tables are constructed by repeated survey of several woods (B), it is often found that the links cross one another for unexplainable reasons.

PARAGRAPH XCIII.

GATHERING DATA FOR NORMAL YIELD TABLES.

In order to see whether or not two woods, in the case C of the preceding paragraph, belong to the same chain of growth, two methods are in use:

a. The horn or curve method, after Baur.

b. The stem analysis method.

Remarks on *a:*

The contents and age of all woods (normal) surveyed are plotted in a diagram, the age forming the abscissa and the volume the ordinate of the system.

Curves are then drawn outlining the maxima and minima of growth observed.

The horn-shaped space between these curves is divided into a number of sectors equal to the number of yield classes to be distinguished. The middle line of each sector illustrates the productiveness of its class.

The average height growth is obtained in a similar way, the height data forming the ordinates in a system of co-ordinates.

Baur finds that the allotment of a given plot to a volume-sector corresponds with its allotment to a height sector. In other words, the height is, after Baur, an absolutely reliable indicator of the quality of the soil, or, what is the same, of the yield class.

The growth of sectional area, height and volume being known, the development of the form factors for the various sectors is readily obtained from the fraction $\frac{v}{s \times h}$.

Remarks on *b:*

An analysis of the average stems in lots surveyed would not throw any light on their connection as members of one and the same chain of observation. After Robert Hartig, the 200 strongest trees are analyzed. After Wagener, the ideal cylinders merely of these 200 strongest stems are analyzed by ascertaining their height growth and their diameter growth at breast height. Weise and Schwappach are satisfied with an analysis of the heights merely of the 200 best stems.

The selection of sample plots is not easy, even in second growth raised under forestal care. A valuation survey establishes for each plot the number of stems and the sectional area for each diameter class of stems (usually divided into 5 classes); further, the average age and the average height of the plot. The volume is then figured out, usually, according to the Draudt-Urich method.

The experiment stations maintained by the European Governments control the growth of a large number of experimental plots, which should not be smaller than ½ acre each.

The sample plots are corner marked, and, more recently, the individual trees contained therein are numbered consecutively. Surveys of these plots are made every five years. The point of measurement is indicated by a chalk line.

In America normal sample plots have not been established as yet by the Bureau of Forestry in second growth. The sample plots at Biltmore do not represent a normal second growth.

PARAGRAPH XCIV.

NORMAL YIELD TABLES, THEIR PURPOSES AND CONTENTS ABROAD.

Normal yield tables are especially used for the following purposes:

1. To ascertain the quality of the soil (*e. g.*, for taxation).
2. To ascertain the volume of the growing stock.
3. To ascertain future yields of the forest.
4. To solve problems of forest finance, especially those of forest maturity (length of rotation).

German normal yield tables have the following contents:

A. Tables for the main forest—the secondary forest comprising such trees on the same lot as are about to be removed by way of thinning:

(1) Age, graded at five year intervals.
(2) Number of trees.
(3) Sectional area at chest height, inclusive of bark.
(4) Average diameter.
(5) Average height and height increment.
(6) Volume in cubic measure arranged according to assortments as logs, fuel, bark, etc.
(7) Periodical and average annual volume increment.
(8) Increment percentage.
(9) Form factor.
(10) Normal growing stock.

B. Tables for the secondary forest, giving merely its volume, which, as stated, is to be removed by way of thinning.

Circular 445 of the Bureau of Forestry defines "future yield tables" as follows: "A tabular statement of the amount of wood which, after a given period, will be contained in given trees upon a given area expressed in board feet or some other unit."

PARAGRAPH XCV.

RETROSPECTIVE YIELD TABLES.

In "retrospective" yield tables an attempt is made to rebuild the growing stock as it was before lumbering from the stumps found on the ground and from stem analyses of the trees now standing. Prerequisite is a knowledge of the year in which lumbering took place and of the conditions of growth since prevailing.

Method of proceeding:

1. Make stem analyses and construct tree volume tables, showing the probable contents of trees for stumps of a given diameter and for given diameters b. h.

2. On land cut over *n* years ago, find by valuation survey and stem analyses:

a. The present volume "F."

b. The volume "y" of the trees now standing as it was "n" years ago with the help of tree volume tables.

c. From the stumps the volume "x" of the trees logged "n" years ago.

3. A product of "F" units (with an undergrowth not fit for logging) has been derived in "n" years from an original stand aggregating "y" plus "x" units of volume.

4. Grouping hundreds of sample plots together, yield tables for local use are obtained. Misleading is, of course, the multiplicity of conditions (mixture of species, soils, original stands, pasture and fire) surrounding a second growth which check the applicability and the combination of the tables found.

The tables are way signs, not ways, toward a true knowledge of the productiveness of cut-over woodlands.

PARAGRAPH XCVI.

YIELD TABLES OF THE BUREAU OF FORESTRY.

Bureau yield tables are meant to show the growth on cut-over land occurring within the next 10, 20 or 30 years, if a tract is logged to a 10", 12" or 14" (or any other) limit. Bureau yield tables are based on tree volume tables and on an account of the numbers of tree individuals found in the various age classes of forest, viz., diameter classes of trees.

The influence of the different qualities of soil on tree growth is not given, only one average volume table being constructed. The volume tables show the number of years which a tree requires to increase its diameter b. h. by one inch. The volume tables record, in addition, the volume increase corresponding with such diameter increase. Applying these findings to the stumpage presumably left after logging, the volume can be ascertained which is expected to be on hand 10, 20 or 30 years later. The volume growth is forecasted, as if it were taking place under primeval conditions.

The Bureau neglects entirely the death rate of trees, due to natural causes and especially high amongst seedlings and saplings, or else due to the logging operations themselves. The results forecasted in this way must be invariably too high.

Pinchot's Spruce Tables (The Adirondack Spruce, p. 77) are based on similar premises:

a. Construct volume tables by stem analysis (stump-analysis) on land cut over for a second time, thus showing rate of growth for trees left standing at the first cut.

b. Construct tables, by actual measurements in the woods, giving the number of trees of the various diameters, composing a stumpage of from 1,000 to 12,000 feet board measure.

c. Predict the number of trees and their exact diameters to be found 10, 20 or 30 years after logging, according to severity of logging (diameter limit).

d. With the help of the volume tables, give the contents of these trees.

In these tables as well, the death rate amongst trees is disregarded. For normal death rate, compare Pinchot's "White Pine," p. 80, ff; also remarks at end of Paragraph LIV.

PARAGRAPH XCVII.

THE INCREMENT OF A WOODLOT.

The current as well as the annual average increment of normal, even-aged woods culminates at a much earlier date than the increment of the trees composing such woods. The explanation lies in the death rate of the trees.

Under a close crown density in even-aged, normal woods, the stronger half of the trees yield, from the pole stage on, practically all the increment, the weaker half of the trees being almost inactive.

The better the quality of the soil, the earlier occurs the culmination of the increment; consequently, on good soil, shorter rotations are apt to be advisable than on poor soil.

Light demanding (intolerant) species show an earlier culmination than shade bearers (tolerant) species.

For white pine woods, after Pinchot, the years of increment culmination are as follows:

Culmination	For entire volume with bark in cu. ft.			For volume Doyle in ft. b. m.		
of	I.	II.	III.	I.	II.	III.
Current incrt....	40th	50th	60th yr.	70th	70th	110th yr.
Average incrt...	60th	80th	100th yr.	135th	160th	210th yr.

I denotes best; II denotes medium, and III denotes poorest quality of soil.

The increment of a woodlot, whether normal or abnormal, can be obtained:

a. With the help of yield tables.

b. By special investigations made into the rate of growth of sample trees (Paragraph XCVIII.).

c. With the help of the average annual increment of the woodlot (Paragraph XCIX.).

The increment of a past period is never exactly equal to that of a future period, unless the age of the woods is close to that year at which the increment culminates. The increment percentage during a past period is always larger than the increment percentage during a coming period (aside of temporary increase due to light-increment).

The general laws (Paragraph LXXV.) relative to the culmination, increase and decrease of increment hold good for the volume increment of woodlots as well as for that of trees.

PARAGRAPH XCVIII.

ASCERTAINING THE INCREMENT OF WOODLOTS BY SAMPLE TREES.

The current annual volume increment and the volume increment percentage of a wood, from which its maturity largely depends, can be correctly found only by a valuation survey, combined with an investigation into the present rate of growth exhibited by a number of sample trees.

Borggreve recommends to gauge the increment of the sample trees by the Schneider increment percentage. This is usually insufficient.

The correct volume increment percentage p of a woodlot is obtained from the volume increment percentage p_1, p_2, p_3, p_4 and p_5 of the class sample trees—which represent class-volumes v_1, v_2, v_3, v_4 and v_5—as

$$p = \frac{v_1\,p_1 + v_2\,p_2 + v_3\,p_3 + v_4\,p_4 + v_5\,p_5}{v_1 + v_2 + v_3 + v_4 + v_5}$$

Where the form heights of the classes differ slightly only, the sectional areas of the classes may be substituted for the volumes of the classes.

Again, where classes of equal sectional area are formed (after Robert Hartig), there the volume increment per cent. of the woodlot equals the arithmetic mean of the volume increment percentages of the sample trees, so that

$$p = \frac{p_1 + p_2 + p_3 + p_4 + p_5}{5}$$

PARAGRAPH XCIX.

CURRENT INCREMENT ASCERTAINED FROM AVERAGE INCREMENT.

Within certain limits, a short time previous and a short time after the culmination of the average annual increment, the annual average increment equals the current increment and can be used in its place as a basis for yield calculation. European Governments frequently prescribe this ***modus operandi*** for yield forecasts in working plans.

CHAPTER IV.—LUMBER

PARAGRAPH C.

UNITS OF LUMBER MEASUREMENT.

For rough lumber one inch thick, or thicker, the unit of measure, known as one foot board measure, is a square foot of lumber one inch thick. This unit is the 1/12th part of a cubic foot.

For rough lumber thinner than one inch, the unit of measure, also known as one foot board measure, is the superficial square foot, and the thickness of the lumber is here entirely disregarded.

All dressed stock is measured and described as if it were the full size of the rough lumber necessarily used in its manufacture. "Inch flooring," *e. g.*, is actually 13/16 inch thick; and "3/8 inch ceiling" is actually 5/16 inch thick.

Standard thicknesses are:

$\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3 x 4″.

Standard lengths are:

in hardwoods 6 to 16 feet;
in softwoods 10 to 24 feet.

In both cases, lengths in even feet (not in odd feet) are required.

A shortness of 1″ or 2″ in the length of hardwood boards is disregarded.

Standard defects are:

I. In hardwoods: one sound knot of $1\frac{1}{4}$″ diameter;
one inch of bright sap;
one split, its length in inches equalling the contents of the board in feet b.m.

II. In softwoods: sound knots, viz.:
(a) pin-knots of not over $\frac{1}{2}$″ diameter;
(b) standard knots of not over $1\frac{1}{2}$″ diameter;
(c) large knots of over $1\frac{1}{2}$″ diameter;

pitchpockets, viz.:
(a) small pitchpockets $\frac{1}{8}$″ wide;
(b) standard pitchpockets up to $\frac{3}{8}$″ wide and up to 3′ long;

pitchstreaks, viz.:
(a) small pitchstreaks not wider than $\frac{1}{12}$ the width and not longer than $\frac{1}{6}$ the length of board;
(b) standard pitchstreaks with dimensions up to twice as large as given under (a);

sap, viz.:
(a) bright sap;
(b) blued sap;

splits, wane, scant width, tongues, less than $\frac{8}{16}$″ long.

The point at which a defect is located greatly influences its effect on the grade of the lumber.

The two faces, the two edges and the two ends of a board must be parallel. In case of unevenness, the thinnest thickness, the narrowest width and the shortest length are measured.

Lumber is measured with the help of a lumber rule (Lufkin rule) which yields for inch boards of given lengths and given width the corresponding contents in feet b. m.

In measuring the widths, fractions of an inch are neglected in rough lumber.

PARAGRAPH CI.

INSPECTION RULES AND NOMENCLATURE.

The lumber inspection prevailing in a given market is governed by local custom or by agreement within the body of local associations of lumbermen.

The tendency of all inspection rules is directed toward a gradual lowering of rigidity.

The wholesaler's inspection is generally stiffer than that of the manufacturer. Diversity of rules is a sadly demoralizing element in lumber circles.

Lumber sawn for special purposes (*e. g.*, wagon bolsters) must be inspected with a view to its adaptability for such special purpose.

A. *Hardwood.* The grade of a board depends on

1. Its width and length;
2. Its standard defects;
3. The percentage of clear stock contained therein;
4. The number of cuttings yielding such clear stock.

The following table shows average specifications prevailing for the various grades of hardwood lumber in the U. S. markets.

The defects specified invariably indicate the coarsest stock admissible in a given grade.

Designation of Grade.	Hardwood Lumber Specifications.						
	Minimum		Actual		Allows of		
	Len'h feet.	Wi'th inches.	Length feet.	Width inches.	No. of standard defects.	Rate of clear stock.	Con'd in c't'ngs not more than
Firsts.......	10	8	10 & over	8 & 9	none	Practically all.	Practically one.
	..	..	10 & over	10 & over	one		
Seconds.....	8	8	8	8 & 9	none		
	..	..	8	10 & over	one		
	10	6	10 & over	6 & 7	none		
	..	..	10 & over	8 & 9	one		
	..	..	10 & over	10 & 11	two		
	..	..	10 & over	12 & over	three		
No. 1 Com...	6	6	6	6 to 8	none	all	1
	..	..	6	9 & over	one	all	1
	8	4	8	4	none	all	1
	..	..	8	5	one	all	1
	..	..	8 & 10	6 & over	....	$\frac{2}{3}$	2
	..	..	12 to 16	6 & over	....	$\frac{2}{3}$	3
No. 2 Com...	6	3	6 to 10	....	....	$\frac{1}{2}$	3
	..	..	12 to 16	....	....	$\frac{1}{2}$	4
No. 3 Com...	4	3	....	....	....	$\frac{1}{4}$	..

B. *Softwoods.* Softwood lumber is inspected from its best side Under "edgegrain" is understood lumber the face of which forms an angle of less than 45 degrees with the plain of the medullary rays contained in the board. All other lumber is termed "flat grain" or "slash grain," also "bastard grain."

I. *Finishing Lumber*, 1″ to 2″ thick, dressed one or two sides.

1. First and second clear,
   up to 8″ wide; absolutely clear;
   10″ wide; one small defect permitted;
   12″ and over wide; $\frac{1}{3}$ of stock may have one standard knot or its equivalent.
2. Third clear,
   allows of twice as many defects.

II. *Flooring*, 1″ thick and 3″ or 4″ or 6″ wide before dressing; either with hollow back or with solid back;

1. A, B and C flat grain flooring; wherein "A" is clear and "B" allows of one or two standard defects;
2. A, B and C edgegrain flooring; with the same allowance;
3. No. 1 and No. 2 fence flooring.

III. *Ceiling*, $\frac{3}{8}$, $\frac{5}{8}$ and $\frac{3}{4}$ inch thick; 3, or 4, or 6 inches wide.

1. "A" ceiling and "B" ceiling, with small defects only;
2. No. 1 and No. 2 common ceiling, with one and two standard defects, or their equivalent.

IV. *Drop Siding*, which is either "shiplapped" or "tongued and grooved;" it is $\frac{3}{4}''$ thick and $3\frac{1}{4}$ or $5\frac{1}{4}$ inches wide. Grades A, B and No. 1 common.

V. *Bevel Siding*, which scales $\frac{3}{16}''$ at the thin edge and $\frac{1}{2}''$ at the thick edge, resawn from stock dressed to $\frac{13}{16}''$ x $5\frac{1}{2}''$. Grades as under IV.

VI. *Partition*, measuring $\frac{3}{4}''$ x $3\frac{1}{4}''$ or $\frac{3}{4}''$ x $5\frac{1}{4}''$. Grades as under IV.

VII. *Common Boards*, graded as No. 1, No. 2 and No. 3 common boards, 8″, 10″ or 12″ wide, dressed one or two sides, or rough.

VIII. *Fencing*, graded as No. 1, No. 2 and No. 3 fencing, 3″, 4″ or 6″ wide. The grade "No. 3" includes defective lumber with knot-holes, red rot, very wormy patches, etc., on $\frac{1}{2}$ of the length of the board. Fencing is either dressed or rough.

CHAPTER V.—STUMPAGE VALUES

PARAGRAPH CII.

STUMPAGE VALUES.

Forestry is a business; the forest largely represents its business investment; its purpose is the raising of money, of dividends.

Thus it is with investments and the dividends therefrom that the forester is concerned; and it is the task of "forest finance" and "forest management" to ascertain the factors and to regulate the components of such investments.

Forest mensuration, as a subsidiary to forest management, may well devote a chapter to the measurement of the stumpage value of trees.

Stumpage value is the price which a tree brings or should bring if it were sold on the stump.

The stumpage-value of a tree depends on the value of the lumber contained therein and obtained therefrom, deducting the total expense of lumber production (logging, milling, shipping, incidentals.)

Since the value of lumber fluctuates, as well as the cost of production, stumpage values are subject to continuous variation. The tendency of stumpage prices, all over the world, is a tendency to rise—especially so in countries of rapid development, rapid increase of population and inadequate provisions for re-growth.

The cost of production is composed about as follows:

1. Expense of logging and log transportation, varying locally between \$2 and \$5 per 1,000′ b. m.
2. Expense of milling, varying between \$1.50 and \$5 per 1,000′ b. m.
3. Expense of freightage of lumber to the consuming market, amounting per 1,000′ b. m. to \$1.50 for very short hauls; to \$12 for a haul from Atlanta to Boston; to \$21 for a haul across the continent from Portland (Oregon) to New England.

Freight rates have, in the long run, a decided downward tendency. Still, with a majority of the lumber produced in the U. S., the item "freight" forms the chief expense of production.

For Pisgah Forest a reduction of freight rates equalling 1 cent per 100 lbs. involves a net gain for the owner of approximately \$60,000. In this possibility lies one of the strongest arguments for conservative lumbering.

An increase of the price of lumber from \$20 to \$21 at the place of consumption endears the lumber to the consumer by 5%; the owner of the forest now valuing his stumpage at \$5 will eventually experience this increase as a 20% increase of stumpage values.

The only factors of stumpage-values, which the owner himself—unaided by the development of the country—may influence, consist in the expense of logging and log freighting, and in the expense of milling, the former largely depending on the quality of available means of transportation, the latter governed by the quality of the sawmill.

In ascertaining the stumpage-value of a tree the forester considers:

a. The cost per 1,000′ b. m. of logging it, of milling it and of freighting its timber;

b. The volume of timber contained in the tree, by grades;

c. The value of such lumber, by grades.

If a tree contains
45% of lumber worth \$31 per 1,000′ b. m.

It is necessary to find Stoetzer's constant factor of increment or to ascertain the relative increment of the sectional areas of the sample trees at 0.45 of their heights.

35% of lumber worth \$21 per 1,000′ b. m.
15% of lumber worth \$16 per 1,000′ b. m.
5% of lumber worth \$8 per 1,000′ b. m.

then the lumber value of the tree, per 1,000′ b. m., is

$$\frac{45 \times 31 + 35 \times 21 + 15 \times 16 + 5 \times 8}{100} = \$24.10$$

Deducting from this figure the expense of logging, milling and freighting, the actual stumpage-value, per 1,000′ b. m., is derived.

The actual prices paid for stumpage in the U. S. fall deeply below the figures which a test-calculation is apt to yield.

This discrepancy may be explained, above all, by

Ignorance of owners of stumpage;
Agents' and dealers' profits;
Incidental expenses overlooked.

Stumpage-values show a rapid decrease with the increase of the distance separating the tree from the nearest railroad or stream.

The grades of lumber and their proportion obtainable from logs of given species, diameter and soundness (including presence and location of defects) can be ascertained only by test-sawing in the mill.

This has been done in 1896 for yellow poplar at Biltmore (bandsaw mill). The stumpage-values then ascertained are shown by the following table:

MARKET VALUE OF POPLAR STUMPAGE IN WESTERN NORTH CAROLINA, PER TREE, IN CENTS.

At the age of years.	Under good conditions.				Under average conditions.				Under poor conditions.			
	Diam. inches.	Logging and Milling expenses being per 1000 feet B. M.			Diam. inches.	Logging and Milling expenses being per 1000 feet B. M.			Diam. inches.	Logging and Milling expenses being per 1000 feet B. M.		
		$9	$10	$11		$9	$10	$11		$9	$10	$11
100	....	Negative.	Negative.	Negative.	....	Negative.	Negative.	Negative.	....	Negative.	Negative.	Negative.
120	18.8	8	"	"	....	"	"	"	....	"	"	"
140	21.3	40	25	"	18.2	4	"	"	....	"	"	"
160	23.5	105	72	2	20.4	22	5	"	....	"	"	"
180	25.7	265	170	98	22.4	67	35	"	....	"	"	"
200	27.7	445	325	230	24.3	160	103	30	18.5	"	"	"
220	29.6	620	465	350	26.0	287	200	109	20.0	7	"	"
240	....	...	...	...	27.5	430	330	210	21.3	27	3	"
260	....	...	...	...	....	...	460	330	22.1	60	25	"
280	....	...	...	...	....	...	...	...	....	...	45	"
300	....	...	...	...	....	...	...	...	....	...	...	5
320	....	...	...	...	....	...	...	...	....	...	...	30

FOOTNOTE: Dots below a column of figures indicate higher values, not specifically ascertained.

The values above the columns of figures are all negative and were not ascertained specifically either.

It is to be hoped that similar tests will be made for our leading species on a large scale by the U. S. Forest Service or by the various associations of lumber manufacturers. Conservative forestry as a business badly requires data allowing to estimate the actual value of logs, and hence of trees, if the uncertainty of financial results now checking the progress of conservative forestry in America is to be definitely reduced.

BILTMORE LECTURES ON SYLVICULTURE

By C. A. SCHENCK, Ph.D.

Director of the Biltmore Forest School, and Forester to the Biltmore Estate, N. C.

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SYNOPSIS OF PARAGRAPHS.

CHAPTER I.

Foundations of Sylviculture.

CHAPTER II.

The High Forest.

XXIX. Permanent nurseries in particular.
XXX. Seed planting in seed beds.
XXXI. Transplanting in transplanting beds.
XXXII. Protection of nurseries.
XXXIII. Nursing in nurseries.
XXXIV. Special nursery methods proclaimed by renowned sylviculturists.
XXXV. Raising and planting hardwood seedlings on open ground.
XXXVI. Raising and planting softwood seedlings on open ground.
XXXVII. European results of planting experiments with American hardwoods.
XXXVIII. European results of planting experiments with American softwoods.
XXXIX. Difficulties of natural seed regeneration (Enesar).
XL. Age of trees fit for natural seed regeneration (Enesar).
XLI. Methods of natural seed regeneration (Enesar).
XLII. Types in which lumbering precedes natural seed regeneration.
XLIII. Cleared compartment type.
XLIV. Cleared strip type.
XLV. Cleared group type.
XLVI. Cleared selection type.
XLVII. Types, in which lumbering coincides with natural seed regeneration.
XLVIII. Shelterwood compartment type.
XLIX. Shelterwood strip type.
L. Shelterwood group type.
LI. Shelterwood selection type.
LII. Types in which lumbering follows natural seed regeneration.
LIII. Advance growth compartment type.
LIV. Advance growth strip type.
LV. Advance growth group type.
LVI. Advance growth selection type.
LVII. Regeneration of valuable species by natural seed regeneration with, amongst and into companions of weedy character.
LVIII. Pedagogy of the high forest.
LIX. Cleaning in high forest.
LX. Weeding in high forest.
LXI. Improvement cutting in high forest.

CHAPTER III.

The Coppice Forest.

CHAPTER IV.

The Coppice Under Standards Forest.

CHAPTER V.

Propagation of Forest Products Other Than Wood and Timber.

LECTURES ON SYLVICULTURE.

CHAPTER I.

FOUNDATIONS OF SYLVICULTURE.

Paragraph I. Introduction.

Sylviculture means the raising and tending of forest products (wood, bark, deer, stock and other by-products).

Sylviculture was practiced by the ancients only for park or orchard purposes. The first writings on Sylviculture proper appear in the so-called "House Father Literature."

Sylviculture as a discipline was developed by George L. Hartig, Henry Von Cotta and Christian Hundeshagen. European standard books on Sylviculture of more modern tenure are those of Charles Heyer adapted by Schlich) and by Charles Gayer.

European Sylviculture in word and work has, in the course of years, petrified into a set of recipes. It is high time for Sylviculture to be taught and practiced on the basis of Plant Ecology.

For America, European Sylviculture at the present moment is of no more use than Chinese Sylviculture, owing to the great economic differences separating the old from the new country. The ecological principles underlying Sylviculture are, obviously, identical for all countries.

The planting of trees on a large scale is, in this country, now out of the question, since the expense of planting an acre of land usually exceeds the value of an acre of forest. The modern owners of woodlands are not far sighted enough—possibly not credulous enough—to anticipate the arrival of European stumpage prices for a time at which plantations now started will have developed into mature trees.

If we can assume that stumpage in this country will be as valuable in 1980 as it is now in Germany, France and England, then forest planting must be, at least, as remunerative here as it is in the old country (small soil value in the United States).

SYLVICULTURE.

Sylviculture as a discipline comprises the following themes:

A. Ecological principles, facts and definitions.

B. The genesis of the forest.

C. The pedagogy of the forest.

D. The sylvicultural forms.

In the discussion of themes B, C, and D, a distinction is made between the treatment of:

1. High forests.
2. Coppice forests.
3. Coppice under standards forests.

Paragraph II. Ecological factors and their influence on the sylva.

A. Definition.—Plant ecology is a branch of botany showing the dependence and adaptation of plant forms and plant life of and to the surrounding local factors (climate, soil, etc.).

B. Natural laws govern the organization of the species and regulate the communal life (symbiosis) and messmateship (commensalism) of individuals with their own kin, with relatives and with other plants belonging to the same household and feeding at the same table.

C. The most important ecological factors are:

I. Air. Oxygen, nitrogen and carbonic acid, the main components of air, are essential for plant life. The relative proportion of the two integral parts, 79% N., 21% O., varies very little with altitude, latitude and elevation. Salt particles in the air near ocean and sulphuric acid in the air near melting works are very injurious to plant life.

II. Light. Intensity depends on:

Season.
Latitude.
Altitude.

Direct insolation is said to be on the whole of less importance than diffused light (excepting polar regions).

Light is not required for germination of seeds. Without light, however, there is no assimilation, and hence no possibility of tree life. Assimilation increases with increasing intensity of insolation; excessive insolation is, however, destructive. For each species, and for each stage of its growth, there exists a certain optimum, minimum and maximum of insolation with reference to the possibilities of its success. The damaging influence of excessive insolation is prevented by the inner organization of the plant.

The duration (number of days) of insolation is as important as the intensity of insolation. Within the individual tree the lower branches are killed gradually, being overshadowed by new upper branches. Without light no bud; without bud no leafing branch; without new leaves annually formed no limb can live.

Within one and the same species a tree once acquiring superiority over its neighbors is apt to retain superiority until death. Since it enjoys more light, it assimilates better.

Within rival species, owing to greater sensitiveness of chlorophyll and thanks to more favorable inclination, form and position of leaves, some species exceed others in assimilation and vitality under the same influx of light. Shade bearing are such leaves as assimilate sufficiently (so as to bear buds at the axils) in spite of the fact that only little diffused light chances to strike them.

Many dicotyledonous trees form a so-called "leaf mosaic," the lower tiers of leaves fitting themselves into the interstices of light left in the upper tiers. Many leaves alter their inclination toward the sun according to the hourly degree of insolation (photo-metric movement). The epidermis of light demanding and sun-exposed leaves is heavy, leathery. The leaves of shade bearers are thin and wither quickly when picked. Light demanding leaves are often shining, reflecting and whitish, so especially in tropical countries, and the leaf stomata are deeply sunk into the surface. On the same tree leaves growing in the shade are darker than those growing in the light; old leaves darker than young ones.

The formation of spines and thorns indicates a sun plant; hair or down are usually found in light demanders more than in shade plants.

III. Heat.

For each plant and for each step of its development can be determined a minimum, optimum and maximum of heat required or allowed. Without heat growth is impossible, since cell division is impossible. The formation of chlorophyll, breathing, assimilation, germination, flowering, fruiting and transpiration depend on heat. The distribution of the genera is governed, pre-eminently, by heat.

For some polar plants, life is possible below 32 degrees Faht. As a rule, however, plant activity begins to be observable at 50 degrees Faht.

The maxima of heat compatible with plant life generally lie below 115 degrees Faht. Excess of temperature over maximum is more disastrous than deficiency of heat below minimum. Plants, however, temporarily fortify themselves against periodical extremes:

1. By non-freezing cell contents.

2. By reduced water contents (seed, rosin).

3. By lignification.

4. By dropping leaves during winter or during period of excessive drought.

5. By adequate covers (bark, hairs, bud scales, layers rich in air cells, reddish color, wrappings formed by last year's leaves). These covers, at least, allow the plant to escape rapid changes of temperature.

Short periods of vegetation and long periods of rest result from deficient heat. Hence no annual plants in polar regions. Short shoots, evergreen leaves, preparation of flowers in year preceding fruit are characteristic of a polar flora. In tropical countries there are no periods of rest unless determined by periods of drought.

IV. Moisture of air and precipitations.

Water is at hand

a. to increase the toughness of wood (imbibition water of cell walls);

b. to allow of solution of cell contents (cell sap);

c. to serve as plant food, through assimilation;

d. to allow of osmotic movement of sap;

e. to assist in photometric movement of leaves (through swelling and irritation);

f. to reduce rapidity of change of temperature by evaporation.

Only some lichens survive a process of absolute drying. Lack of moisture causes crippled growth, and frequently subterranean forests (mesquit).

After Henry Mayr, the minimum of moisture compatible with tree growth is two inches of rainfall and fifty per cent. of relative humidity during period of vegetation.

Phanerogamous plants are unable to absorb water directly through the epidermis, obtaining it instead through the spongiolae of the roots and, in gaseous form, through the stomata of the leaves. Mosses and lichens, however, absorb water directly through the epidermis. The hygroscopic power of a dead cover of mosses on the ground equals that of a live cover.

Wet climate creates evergreen woods (Pacific coast and Antarctic forests of South America).

A dry climate gives rise to annual species, to a distinct period of rest, to rapid flowering and fruiting.

Precipitations equally distributed over the twelve months of an entire year and precipitations falling during a few weeks result in entirely different floras. Rain in summer stimulates growth much more than rain in winter. De Candolle divides our globe according to moisture and heat and on the basis of floral differences resulting therefrom, into five regions in the fourth of which we are living.

1. Hydromegathermal region (water great heat). Mean annual temperature over 68 degrees Faht. (Amazon river region, wet tropical zone).

2. Xerophilous (Dry loving) region. The region and borders of arid deserts, prairies, sunny slopes, etc., exhibiting a flora very modest in moisture requirements.

3. Mesothermal (medium heat) region, having mean temperature of 59 to 68 degrees Faht. (northern Florida, etc.).

4. Microthermal (little heat) region of 32 to 59 degrees Faht.

5. Hecistothermal (least heat) region of less than 32 degrees Faht.

The most important representative of a Xerophilous character is the Yellow Pine. The hecistothermal zone shows Spruces, Birches, Cottonwoods.

V. Wind.

Wind brings moisture and drought, heat and cold; it covers or uncovers vegetation with sand or snow drifts, tumbling, at prior geographical eras, whole mountains into the valleys (Loess formation). Severe wind dwarfs tree growth and forces branches to grow in leeward direction only. The influence of a slight obstruction, preventing the access of wind at high latitudes, is splendidly illustrated by the growth of Spruce and Fir on Pisgah Ridge. On high mountains tree growth is often entirely determined by wind (slope of Little Ball).

Species resisting wind best in Pisgah Forest are Red Oak, Chestnut, Locust.

Picea alba and dwarf pines like Pinus pungens and montana show great strength in resisting wind. In the west Tsuga mertensiana, Pinus albicaulis, Pinus monticola, further western Juniper rank first among the trees braving severe storms.

Wind is essential for the breathing and for the perspiration of leaves and bark; for driving pollen on stigma to fertilize the seed; for trimming the branches, thus forming clear boles; for distributing seed. The investigations conducted by Fliche (French Forester) have, however, yielded the astonishing result that winged seeds travel much slower than heavy seeds covetted by birds. Fliche gives the following number of years as required by trees traveling from Nancy to Paris, a distance of 160 miles:

Beech ....18640 years.
Chestnut ....12920 years.
Pine ....48680 years.
Sarvis ....1330 to 2000 years.

VI. Structure of soil.

Soil consists of natural rock; or of rock disintegrated under the influence of water, frost, heat, oxygen, carbonic acid, lichens, bacteria; or of washings deposited by water, wind or glaciers.

The components of soil are:

a. Soil skeleton, large grains, principally quartz and stones.

b. Soil flesh, minute semi-soluble particles,—the mud of the rivers.

c. Soil fat, the humose particles giving the soil a dark color.

d. Soil blood, the air and water, filling the pores of the soil. The size of the pores determines the capillary capacity.

According to the resistance which soil offers to spade or plow, we distinguish the following classes:

Light soil;
Loose soil;
Binding soil;
Heavy soil;
Stiff soil.

VII. Air in the soil.

Roots require oxygen for breathing. Like fish, they die from lack as well as from superabundance of oxygen. Subterranean air is rich in carbonic acid exhaled by roots, fungi, bacteria, animals. Swamp soil contains little air. Hence such species only find a living in swamps which have large inner air ducts (Cypress knees, Nyssa root, bamboo, cane breaks, sour grasses).

Prairial soil is naturally so compact that it contains little oxygen.

VIII. Water in the soil.

It occurs:

a. Chemically bound to minerals and salts.

b. Absorbed by the hygroscopicity of soil.

c. Raised by the capillary power of soil.

d. As ground water—lakes, swamps, brooks being merely areas of open ground water.

The size of the pores and the presence of humus govern the intensity and rapidity of water obtention and retention. Sand, for instance, allows water to enter its large pores quickly, but gives it up rapidly as well. Wet, moist, fresh, dry and arid soil are distinguished.

The degree of wetness of soil is of the utmost importance for tree growth. At its southern limit, a species grows only in swamps or along watercourses. The water in the soil dissolves the mineral salts so as to form sap and seems to be of great influence on the bacterial life in the soil.

IX. Heat in the soil.

It is derived from the earth's own temperature, from chemical processes in soil (notably fermentation) and from sun rays. In the latter case, the angle of insolation, the duration of insolation, the heat capacity of soil, the color of soil, the porosity of soil and its vegetable cover serve as influencing factors.

A cold root has no pumping power. Fine root fibres die from temperatures which fine branches easily withstand. The actual influence of the heat in the soil on tree growth is practically unknown. The opening of the buds in spring and the fall of leaves in autumn are probably connected with the thermic changes occurring in the various strata of the soil.

X. Depth of soil.

Flat rooted species easily obtain the superiority over taprooted species on shallow soil. Tree roots, however, are not apt to penetrate to a depth greater than six feet. Shallow soil increases danger from fire, drought, storm. A tap rooted species, planted on shallow soil, produces only a stunted form. Shallow soil is well adapted to the coppice system, in case of broad leaved tap rooted species.

XI. Food in the soil.

A tree, like a crystal, is composed of various chemical elements. The available amount of that necessary element which happens to occur in the relatively smallest degree determines in both crystal and plant, the rate of growth actually taking place (Liebig's law). The superabundance of one component, even of a necessary component, prevents, on the other hand, the local existence of many species.

The ten necessary elements found within a plant in solid, liquid or gaseous condition are O, H, C, P, Fe, K, Mg, Ca, N, S.

"Roots search food as if they had eyes,"—a rule easily proven in any nursery.

XII. Species of soil.

a. Rock. Most important rock formations are: Granite, gneiss, limestone, sandstone, slate and trap.

Vertical stratification facilitates decomposition and tree growth. The various species of rock differ in hardness, porosity, heat conduction, and above all in soluble mineral contents.

b. Quartz sand. Quartz sand is unfertile when pure, since silicic acid fails to be digested by the roots and fails to react with the acids usually found in the soil. Quartz sand is loose, has small hygroscopicity, small capillarity and small heat-retaining capacity. It is hot during the day and cold at night.

c. Lime. Lime when pure is a poor soil, although not quite as dry and hot as sand. Lime, however, mixed with loam and clay (so-called marl) forms an extremely productive soil.

d. Clay. Clay has great absorbing and hygroscopic power. It is wet and cold. Main components are aluminum-silicates.

e. Loam. Loam is a mixture of sand and clay—the usual soil in agriculture and forestry. It is usually colored by iron (red loam at Biltmore). We speak of a sandy loam or of a loamy sand according to the prevalence of one or the other component. Loam soil exhibits a happy medium of qualities favorable to tree growth.

f. Humus. Humus results from the decomposition of vegetable and animal matter under co-operation of bacteria, fungi, rain worms (Darwin), larvae. Humus forms a solvent of mineral plant food. A bad conductor of heat and cold, it prevents rapid changes of temperature in soil, has great hygroscopicity and great water-retaining power and is a preventive to evaporation of soil moisture.

Mild forest humus shows a basic reaction, whilst the sour humus of the swamps shows an acid reaction.

Unfavorable is the dust humus formed by many Ericaceae.

XIII. Physical versus chemical qualities of soil.

Agriculture withdraws food only from the top layer of soil. It deprives that top layer of its rarest and most valuable components, by the annual crop of grain excessively rich in nitrates, phosphates and potash. The porosity, and through it the water capacity and the heat capacity of soil, are readily controlled on the field by the plow. It is necessary in agriculture, in the long run, to return to the soil in the shape of fertilizer annually as many pounds of nitrates, phosphates and potash as have been removed in the shape of crops from a given acre of land.

The productiveness of agriculture depends, above all, on the chemical qualities of the soil tilled. A crop of trees, on the other hand, takes from the soil very little, since the tree consists mainly of C, O, H, or since wood is nothing but air solidified by sunshine. The phosphates, nitrates and potash absorbed by the tree are returned to the soil by the fall of branches, leaves, seeds, flowers, etc.

The traces of chemical fertility locally removed in the shape of logs are, in addition, counterbalanced by the decomposing influence on the rock exercised by roots and root-bacteria.

Hence it is not likely that a rotation of crops, as is required in fields, has any advantages in the case of forestry. In primeval woods, we know that Nature allows a species to succeed itself.

The physical qualities of the soil preeminently influence the tree species and the rate of its growth. The chemical qualities of the soil play the most potent role in the case of agricultural species.

Soil fit for agriculture is not necessarily good forest soil (prairies). Soil fit for forestry (strong north slopes) is often utterly unfit for farming.

XIV. Soil covers.

Soil covers are either dead or living. Dead soil covers are snow, debris of leaves and twigs. Living soil covers consist of mosses, grasses, etc.

Snow keeps the soil warm, prevents rapid changes of temperature, prevents young plants covered by it from perspiring, prevents lifting of plants by frost.

The debris on the ground feed millions of animals and fungi; they harbor, on the other hand, mice, larvae and other enemies of plant growth. Debris frequently prevent reproduction from self-sown seed and increase the severity of forest fires. Living as well as dead soil cover influences evaporation of moisture, porosity of soil and water drainage.

XV. Life in the soil (Compare Swiss L. F. F. 1904, May and June).

The soil lives like a plant or an animal, since it shows continuous changes of form and of composition. Very little, however, is known of the life and the interdependence of millions of live individuals found in the soil. Certain it seems that tree growth is bound on the presence of certain fungi and bacteria living on the roots (Mycorrhiza). Most important are the bacteria capable of digesting the nitrogen of the subterranean air. Leguminous plants (Clover, Black Locust) are beset with root knobs, containing bacteria busily engaged in the assimilation of nitrogen. The hyphae of a fungus called Frankia play a similar role on the root knobs of Alder and Sweet Fern. After P. C. Mueller, Spruce will grow on poor sand lacking nitrogen if Pine is mixed with it, furnishing nitrogen through its mycorrhiza.

The maximum number of bacteria is said to be found two feet below the surface of the ground, and none exist below six feet. The number of bacteria per pound of soil varies from one hundred million to two hundred and fifty million.

Important, too, in plant ecology is the life of the larger animals (worms, insects, centipeds) changing the vegetable matter of the soil into manure proper, mixing mineral soil and vegetable matter, increasing the porosity, drainage and aeration and neutralizing the acids of the soil. Shade, protection from wind and sufficient moisture are beneficial to animal life in the soil.

Paragraph III. Influence of the sylva on the ecological factors.

The influence exerted by the forest on local climate (heat, air, precipitations, etc.) is dwelt upon in the lectures on forest policy.

Whilst the ecological factors shown in the previous paragraph exhibit the important influence which the soil has on the tree, there exists at the same time, although to a lesser degree, an influence of the tree on the soil. This influence is invariably such as to facilitate life to the tree itself and to its progeny. The production of humus is the main source of that influence.

Governing factors are:

A. Leaf canopy overhead. Evergreen as well as deciduous woods annually return to the soil by the leaf fall a large amount of dead matter readily assimilable. Shade bearers furnish a better humus than light demanders, excluding, at the same time, intensive insolation, so that the decomposition of the leaf carpet and the evaporation of the soil moisture is favorably retarded.

A humus formed by Beech, Maple and Chestnut is considered especially good. Beech is justly called abroad the "Mother of the Forest," owing to its soil-improving qualities. The leaf canopy is particularly dense during the thicket and the pole-wood stage. Even light demanders, whilst young, improve the fertility of the soil. At a higher age, when the light demanders place themselves far apart one from another (say less than 100 trees per acre), the humus on the ground is destroyed, being replaced by a dense and impermeable matting of grasses or shrubs.

Amongst the conifers, Yellow and White Pine seem to furnish the best humus. Spruce humus is too waxy.

B. Rate of disintegration of leaves.

This rate depends on insolation, on heat capacity of soil (sand versus clay), on atmospheric humidity. Uusually, decomposition of leaf fall takes place within two or three years. The thin leaves of the shade bearers decompose quicker than the heavy leaves of the light demanders. The high atmospheric moisture of high altitudes causes accumulation of large quantities of leaves. In the tropics there is little litter on the ground.

C. Root system.

It is the decaying root which allows the precipitations to trickle down to the lower strata of soil. Hence tap rooters seem more efficient than flat rooters in converting a rapid surface drainage into a slow underground drainage. Decomposing the rock by chemical action, the tap root forces it to yield its soluble salts.

D. Soil improvement through root-bacteria and fungi.

The upper layers of forest soil are densely peopled with the hyphae of basidiomycetes, living on humus. Leguminous trees (Locust, Kentucky Coffee tree, etc.) by their root-bulbs increase the fertility of the soil, and the Alders seem to act in a similar way. On abandoned fields in Pisgah forest the soil is improved by Sumac, Sassafras, Locust, etc. These species act as ushers for more exacting forest growth, improving the physical conditions of the soil.

Very little is known about the nature of the improvements.

Paragraph IV. The North American Sylva.

The northern limit of the forest coincides with the isothermal line, 30 degrees Faht., which lies on the west side of the continent at 70 degrees latitude in Alaska (under influence of the Japan current), and on the east side at 55 degrees latitude in Labrador and at the Hudson Bay.

The rainfall and, consequently, the existence of forest depends on the moist sea winds supplied by the Pacific, the Atlantic, the Gulf and the Great Lakes. A cross-section through North America at the latitude of Lake Michigan and Portland, Oregon, shows the inter-dependence between the lowest gaps in the mountain chains and the forest on the next mountain chain lying to leeward. For instance: lowest gap in Coast Range at 3,000 ft. above sea level; no forest in Cascades below 3,000 ft.; lowest gap in Cascades at 4,000 ft. above sea level; no forest in Blue Mountains below 4,000 ft.; lowest gap in Blue Mountains at 5,000 ft. above sea level; no forest in Rockies below 5,000 ft.

The east slope of the Coast Range, Cascades, Blue Mountains and Rockies shows little or no forest, and the lowlands to the east of the mountain chains are deserts and prairies.

Moist sea winds, after passing one chain allow the forest to grow on the next chain only above the altitude of the gaps in the first chain.

The following table shows the composition of the forest of the United States and of Canada, under the influence of the climate:

Percentage of forest area occupied by:

	In United States.	In Canada.
Tropical forest	½%	0%
Sub-tropical forest	15 %	0%
Forest of the moderately warm zone	75 %	10%
Forest of the moderately cold and alpine zone	9½%	90%

The United States contain two big and one minor forest region, namely the

Atlantic forest region;

North Mexican forest region;

Pacific forest region.

The Atlantic and the Pacific forest join under the influence of the Hudson Bay winds at 52 degrees latitude, in Assiniboia. There are no prairies proper north of this latitude.

The tropical forest shows no seasons. Its species are evergreen. In the United States it is found only at the extreme southern point of Florida.

The sub-tropical forest is characterized by the evergreen broad-leaved trees, and is the zone of rice and oranges, extending in eastern North America to 35 degrees, in western North America to 40 degrees, latitude.

The moderately warm forest region is the zone of the broad-leaved deciduous trees, of corn, vine and wheat.

The moderately cold forest region is that of the evergreen conifers too cold for the production of corn.

In North Carolina a trip from the coast to the high Balsams leads the traveler from the northernmost limit of the sub-tropical through the moderately warm forest region into the southernmost limit of the moderately cold forest region which sets in at about 6,000 ft. elevation.

A. The Atlantic forest.

I. Eastern tropical forest. Mahogany occurs only as a small tree; Palms and other typically tropical orders (Sapotaceae, Ebonaceae, Euphorbiaceae, Verbenaceae) compose the forest. It must be remembered that Southern Florida exhibits only the extreme northern occurrence of the tropical forest.

II. Eastern sub-tropical forest. It shows evergreen Oaks, Magnolias, Persea, etc., besides the Pines, the soil being too poor for the formation of a large wintergreen broad-leafed forest. The winter temperature averages 53 degrees Faht.; precipitations are heavy; relative humidity is 75 degrees. Sabal palmetto is a characteristic weed. Bald Cypress and Cuban Pine are characteristic trees of the region. Among the other Pines, the Long Leaf Pine is the most important, associated in the north and west with Pinus clausa, echinata, taeda, serotina, glabra. Liquidambar, Nyssa and Fraxinus platycarpa occur in swamps at the edge of which southern White Cedar frequently appears.

III. Eastern winter bald forest of the moderately warm zone. It is fringed at the south, north and east by a broad belt of Pines, which belt connects this region at the south with the sub-tropical forest, at the north with the Fir and Spruce forest of the moderately cold zone. It is divided into a northern and a southern half by the 39th degree of latitude. Each half shows an Atlantic, a central and a prairial sub-region.

a. South Central sub-region. Traversed by the Mississippi, the sub-region is characterized by high temperatures, large precipitations and fine soil, which allow of the best development of broad-leaved woods found in the world. Twenty-three Oak species, eight Hickory species, two Walnuts, Buckeyes, Chestnut, Gums, Cottonwoods, Yellow Poplar, Sycamore, Beech, Maple, Elm, Red Cedar, etc., stand in a dense undergrowth formed by Dogwood, Kalmia, Rhododendron, Hazel, Cherries, Hawthorn, Buckthorn, Witch Hazel, etc.

In this sub-region the heavy seeded broad-leaved trees obtain the maximum of size, quality and number of species at altitudes running up to 3,000 ft. Higher up the number of species diminishes. At 5,000 ft. only Red Oak, Chestnut, Beech, Buckeye, Sugar Maple (resembling north central subdivision) are found, and at 6,000 ft. the Spruces and Firs (southernmost sentinels of moderately cold zone) set in.

b. South Atlantic Sub-region. It comprises the Eastern foothills of the Alleghanies (Piedmont Plateau) and part of the Coastal Plain. Temperature 3½ degrees Faht. less, soil poorer, precipitations less abundant than in the South Central Sub-region, hence much Pine (taeda, mitis, rigida, virginiana). Only ten Oak species; White Cedar swamps; broad-leaved flora otherwise as in South Central, but of rather inferior development.

c. South Prairial Sub-region. Extending from the 92nd to the 102nd degree of longitude, the forest appears poorer than the annual temperature and the annual rainfall seem to indicate; a discrepancy between cause and effect, possibly due to forest fires. West of the 95th degree of longitude, Oak, Ash and Walnut occur along rivers, especially on Eastern banks. Oak also appears scattered through the depressions.

d. North Central Sub-region. Precipitations very abundant from South as well as North. Average winter temperature 30 degrees Faht. Quick change of temperature. The light-seeded, broad-leaved species reach maximum in this section, also White Pine and Hemlock. Six Maples, five Birches, Elms and Lindens, further Ash, Butternut, Red and White Oak compose the forest.

e. North Atlantic Sub-region. Plenty of moisture, the mountains being close to the sea-shore, but not so much as in Lake states. Average winter temperature 34 degrees Faht. at seashore. Pinus rigida and mitis, Beech, Birch, Chestnut, Maples, often replaced by Poplar and Willow. Spruce sets in at altitude exceeding 1,000 ft., accompanied by Hemlock, White Cedar, Red Cedar, White Pine and Tamarack.

f. North Prairial Sub-region. Dry summers, blizzardy winters and more sandy soil. No Hemlock. Red Pine and Jack Pine intruding fom North. Scrub Oak openings. On best soil still good development of Linden, Maple, Elm and Birch. White Pine of poorer quality than in sub-region "d."

IV. Eastern Evergreen Forest of the moderately cold zone.

The majority of this zone lies in Canada, in northern Lake states, Maine. It occurs in North Carolina at 6,000 ft. elevation; in the Adirondacks at 2,000 feet; in Maine at sea level.

The region occupies a big belt stretched across the continent, so that western and eastern flora joins hands in it. A typical tree of this region, the White Spruce, often forms large pure forests. Other species of the zone are Red Spruce, Black Spruce, Balsam-fir, Cottonwoods, Canoe Birch, Hemlock, White Cedar and Tamarack, the latter here obtaining its optimum.

B. The North Mexican forest.

The North Mexican Flora intrudes, coming from Mexico, Arizona and New Mexico. It is different from the Pacific flora, unimportant commercially, interesting only botanically. Forest possible only at altitudes exceeding 5,500 feet. Forest proper—dense forest—only at 8,000 feet.

I. North Mexican sub-tropical forest.

Characterized by Cactus, Yucca, Agave and Mesquite (Prosopis). Evergreen Oaks in moist valleys. Madrona (Arbutus), a beautiful tree, on sunny slopes often mixed with Manzanita (Acrostaphylos pungens).

II. North Mexican forest of the moderately warm zone.

This zone, very narrow, should contain winter-bald broad-leaved species. The dryness of the soil and of the air, however, allows of their occurrence only on moist ground along rivers. Western Walnut, Mexican Ash, Poplars and Willows. The Pines are the leading species of the zone, forming huge forests at altitudes exceeding 6,000 feet elevation. Some of these Pines are northern sentinels from Mexico, others outposts from the States. Most important is Pinus Chihuahuana, in Mexico largely used for timber, up to 80 feet high, three feet in diameter, three needles. Pinus Arizonica, a five-needled pine, occurs at 6,000 feet elevation. Pinus reflexa, locally known as White Pine, occupies moist dells at 8,000 feet elevation. Nut pines at lesser elevations as low brush, notably Pinus edulis, monophylla osteosperma.

C. The Pacific forest.

Typical difference from Atlantic forest lies in the relative lack of broad-leaved woods—not in species, but in area. Tropical forest is absent, possibly due to lack of moisture at low elevations in Southern California.

I. Pacific sub-tropical forest.

Occupying Southern California. This zone is devoid of dense forests, the northern edge excepted. Evergreen Oaks, or rather Winter Green Oaks (Quercus densiflora is leafless during dry summer) dot the ground in park-like groves. California Laurel (Umbellularia californica) is a characteristic tree of this region, growing up to 100 feet high. Impenetrable bush thickets cover hot aspects, formed by Leguminosae, Labiatae, Compositae, Rosaceae, etc. The rare and beautiful Montery Cypress along the seashore. Sequoia sempervirens is the biggest tree of the zone, found only at its edge in the Coast Range. Pinus insignis known as Montery Pine is valuable on sand dunes.

Pinus tuberculata (attenuata) occurs most frequently in even-aged woods. Pinus sabiniana, Nut or Digger Pine, valuable for the Indians, of Olive-like appearance, is mixed in the Oak parks and in the Chaparal thickets. Another Nut Pine is Pinus parryana, growing 30 feet high. Pseudotsuga macrocarpa on St. Bernardino range. Eucalyptus and Accacia were successfully introduced from Australia, Oranges and Figs from the Orient.

II. Pacific forest of the moderately warm zone.

This zone covers the major part of Oregon and Washington and the mountains of Northern California. It is characterized by very even annual temperature and high precipitations. Here the winter bald broad-leaved species should rule supreme. The winter bald Oaks are represented in Oregon by Quercus garryana (White Oak), in California by Quercus Kellogii (Black Oak), Fraxinus Oregona, Acer macrophyllum, Populus trichocarpa (Black Cottonwood, the biggest Cottonwood of the world) occupy the bottom land along the rivers; further Sorbus, Amelanchier, Crataegus, Prunus, Salix, Aesculus, Alnus, Acer, Platanus, Negundo, Betula. All of these latter species unimportant commercially.

In strict contrast with the Atlantic forest of the same zone, the conifers rule in importance, foremost among them the Douglas Fir (Pseudotsuga taxifolia) which stands temperature of 15 degrees Faht. easily. Best development on west slope of Coast Range. In the Rockies, it forms only summer shoots and short boles, owing to shorter growing season and lack of atmospheric moisture. In Colorado, Arizona, New Mexico occurs a gray variety. In the Sierras it appears only as a dependent species.

Pinus ponderosa (Yellow Pine, Bull Pine). Height and timber quality depend on proximity to Pacific Ocean. Optimum in Sierra Nevada, where trees 300 feet high are frequently found. Very heavy sap-wood. Name ponderosa undeserved. No tree of the United States occupies a larger territory or shows greater adaptability.

Chamaecyparis lawsoniana (Port Orford Cedar) occupies only a very small territory close to the Pacific Coast. Does not ascend mountains to over 1,500 feet. Heavy shade bearer, splendid reproduction.

Thuja plicata (Red Cedar of the West) up to 170 feet high. Rare in California. Best development in Oregon and Washington and Northern Idaho, where it occupies only the moister coves. Boles very tapering; shade bearing; thin bark.

Libocedrus decurrens (White Cedar, Bastard Cedar) on west slope of the Sierras at medium elevations, where the tree is mixed with Abies concolor, Yellow and Sugar Pine. Regeneration easy, often in places previously occupied by the Pines.

Pinus lambertiana (Sugar Pine), a White Pine since it has five needles in a sheath. Specific gravity even less than that of Eastern White Pine (Pinus strobus). The biggest Pine of the world. Very large cones. Optimum in Sierras at 5,000 feet elevation; occurs often with Sequoia, Libocedrus, Abies concolor, Yellow Pine, Pinus Jeffreyi. The latter, a very close relative to ponderosa and distinguished from it by bluish shoots and needles bent towards the shoots, occupies the lower Sugar Pine belt. It prefers moist ground and reaches only one-half the size of ponderosa.

Mayr groups the above trees as follows, according to their demands on moisture:

Demands on soil moisture:

1. Libocedrus decurrens,
2. Pinus jeffreyi,
3. Abies concolor,
4. Pinus lambertiana,
5. Pinus ponderosa.

Demands on air moisture:

1. Abies concolor,
2. Pinus lambertiana,
3. Pinus jeffreyi,
4. Libocedrus decurrens,
5. Pinus ponderosa.

Abies grandis (White Fir of Northern Pacific Coast). The only fir on Vancouver Island. Optimum at coast in Oregon where it grows up to 300 feet high, standing alongside gigantic Cottonwoods; extends eastward across the Northern Rockies, and is the first Pacific fir met by the traveller going west on the Northern Pacific. Requires moist soil.

Abies concolor (White Fir of Colorado and of the Sierras). Running south to the San Bernardino mountains, where it occupies elevations of up to 10,000 feet. Traversing Nevada, it occurs in Colorado (gardener's variety glauca). It accompanies Sugar Pine and Bigtree. After Muir, always mixed with Abies magnifica, occuring at altitudes ranging between 5,000 feet and 8,000 feet.

Abies bracteata (Santa Lucia fir of high mountains) occurs in Southern California in moist cool dells.

Tsuga heterophylla (Black Hemlock of low elevations). A fine tree, the progeny of which forms a dense undergrowth underneath Douglas fir. Heavy shade bearer, requiring plenty of moisture, occurring in Alaska, Coast range and Cascades.

Picea sitchensis (Tideland Spruce). Along coast on very moist soil in Washington, on dryer soil in Alaska, very shade bearing and branchy. Stinging needles. Up to 200 feet high.

Sequoia Washingtoniana (Bigtree). Occurring only in the Sierras in scattered groups at elevations ranging from 4,000 to 7,000 feet.

Enormous seeding capacity and sprouting capacity. Average diameter 20 feet, height 275 feet, age up to 4,000 years.

III. Pacific forest of moderately cold zone.

This zone is economically of no importance, although it is the forest zone proper, owing to the impossibility of agriculture within this zone. It is "The Canadian Forest Zone." It lies in the Sierras at 8,000 feet, in the Cascades at 4,000 feet, and in Alaska at seashore. The forests of the Northern Rocky mountains belong to it preferably.

Pinus murrayana (Lodgepole Pine). Shade bearing, in close stands, very branchy, very sappy, retaining cones, easily destroyed by fire, closely related to the Jack Pine of the east. Frequent on old burns, typical for Yellowstone Park, going south to Arizona.

Larix occidentalis (Western Tamarack). Splendid lumber tree, often in pure forests, optimum in Montana, natural regeneration easy, rapid height growth, little sap wood, timber equal to Long Leaf Pine.

Pinus flexilis (Limber White Pine). More branchy and much shorter than eastern White Pine; forms open forests on south slopes of Sierras and in Nevada at 7,000 feet elevation; from Montana it extends southward to Colorado.

Pinus monticola (Mountain White Pine). In Cascades, British Columbia, Idaho, Montana, in the latter state more on slopes draining westward.

Abies nobilis, amabilis, magnifica, the Red Firs of the west. Magnifica known in California as Larch. The two first named often associated with Abies grandis and more frequent in Washington and Oregon than in California. Amabilis extends into Alaska. Red Firs are lacking in the Rockies. Needles are dark.

Picea engelmanni (White Spruce). At home in middle and southern Rockies, on northern slopes at altitudes averaging 10,000 feet.

Picea parryana (Colorado Blue Spruce). Needles very pointed and stinging, of a bluish tint. Occupies moist ground.

IV. Pacific forest of the Alpine region.

Typical trees are:

Pinus albicaulis (Dwarf White Pine). Occurring in the Cascades and the Rockies (Utah).

Pinus balfouriana and aristata (Fox-Tail Pine). White Pine found in California at 8,000 feet to 12,000 feet elevation; twigs thin, retaining needles for many years.

Abies lasiocarpa (Balsam). At edge of tree growth only a shrub. In Colorado at lower, warmer situations a valuable tree. Occurs in all states of the west.

Larix lyallii (Larch of British Columbia). Occurs here and there in Washington, Idaho and Montana, at very high altitudes.

Tsuga mertensiana (Hemlock). A storm-battered hemlock, at high altitudes in Sierras, Cascades, Montana. A branchy tree up to 100 feet high, inaccessible and hence of no value.

Paragraph V. General definitions and explanations.

A. In Europe, under the term "Wood" is understood an aggregate of trees of such uniform character that it can be subjected to the same manner of treatment. In the American virgin forests, "woods" are rare. As a matter of fact the term "woods" as well as the term "forests" has no definite meaning in America. A forester should keep in mind, however, that a plantation or a natural regeneration, whatever its age and its condition, must be classed under the heading "forests."

A "group" of trees consists of even-aged specimens of the same species and is larger than a bunch, clump, or cluster. No recognized definitions of the term "group" and "clump" are at hand, unfortunately, based on the space or the acreage covered by them as units. Groups, as understood in the following pages, are distinct aggregates of trees covering $\frac{1}{10}$ to 4 acres.

B. Pure forests, pure woods, pure groups or bunches are such as contain one timber species only, 5 per cent. admixture being permissible. Species able to form pure forests are termed gregarious or ruling species, sub-divided into distinctly ruling species, which are usually found in pure stands, and conditionally ruling species, which are occasionally found in pure stands.

I. After Drude, the participation of a species as a mess-mate at the forest table is expressed by the following terminology:

a. Social species, denoting the main character, the striking feature (in numbers and volume) of the forest; the rank and file of the forest.

b. Gregarious species, occurring in clumps and groups, island like;

c. Copious species, interspersed with others, the degree of frequency being interpreted by exponents, f. i., $copious^3$, $copious^2$, $copious^1$;

d. Sparse species, occurring isolated and in single specimens;

e. Solitary species, very isolated and very rare.

II. It might be preferable to express the ratio of the participation in per cent.

Social, forming 60% and over of growing stock.

Gregarious, forming 40% and over of growing stock.

Copious, forming 20% and over of growing stock.

Sparse, forming 1% and over of growing stock.

Solitary, forming less than 1% of growing stock.

Intermediate stages might be indicated by a union of the given designations, f. i., "social-gregarious."

III. The configuration of the ground and the rapidity of its change vitally influence the possibilities of a species as a component of the forest.

IV. Species which are not, or which are locally not, "ruling" species are called "dependent" species.

A species might be ruling in North Carolina, while it is dependent in South Carolina. The distribution of the species is limited by its demands on soil and climate. Far away from the center of distribution a species is likely to be dependent.

V. The ruling species in the south are: Long Leaf Pine, Bald Cypress, Loblolly Pine, Short Leaf Pine, Sweet Gum, Post Oak, Cottonwoods, Chestnut.

The ruling species in the west are: Lodgepole Pine, Pinus ponderosa, Douglas Fir, White Fir (Abies grandis), Engelmann's Spruce, Western White Pine, Port Orford Cedar, Redwood, Sitka Spruce.

VI. Obviously the meek species are those that conquer the globe. With the inroads of civilization on the fertility of the soil, and especially on the water capacity of the soil, these meek species obtain additional chances to supersede the exacting species.

C. Weapons of the species in the struggle for existence are:

I. Shade-bearing qualities.

II. Modesty as regards the fertility of soil, the moisture and the heat during the period of vegetation.

III. Power of resistance to storm, sleet, snow, late and early frosts, droughts, fire, etc.

IV. Immunity from forest insects and forest fungi.

V. Longevity. Oak lives longer than Beech; Sequoia longest of all.

VI. Reproductive power, especially reproductive power from stumps, frequency and richness of seed years.

VII. Portability and sensitiveness of seeds; number of enemies of seeds; germinating percentage of seeds.

VIII. Rapidity of height growth in early youth.

D. Density of stand. Every ruling species shows a particular density of cover and a particular ramification during every stage of its life, when grown in pure forests.

I. Density of leaf cover overhead.

a. The form of the crown of the individual depends on side-shade, topshade, neighborly friction and quality of soil.

b. Natural regeneration causes a greater density of cover than artificial regeneration, certainly during the thicket and pole stage. Other influencing factors are: quality of the soil, age of the forest, inroads by snow break, wind fall, fire, deer, fungi, insects.

c. A dense canopy overhead produces clear boled timber and allows of a heavy layer of humus on the ground. The method of regeneration distinctly influences the value of the timber to be formed.

II. Number of trees per acre.

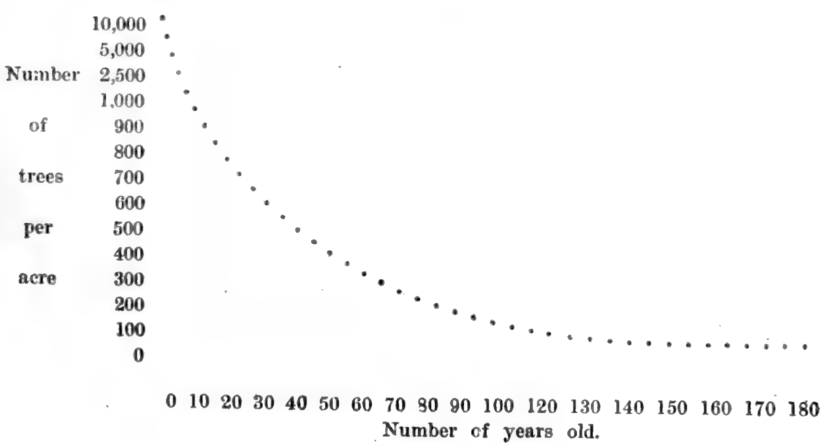
Under normal conditions an acre of pure forest contains the more specimens of equal height or diameter, the better the quality of the soil and the better the climate; and the more specimens of the same age, the poorer these factors are. For example—Yellow Pine Forests:

Number of trees per acre.

Soil.	Boles 75′ long.	Diameter 12.″	Age 60 yrs.
I quality...	320	240	380
II quality...	240	215	460
III quality...	190	190	540

During the pole stage and tree stage shade bearers exhibit per acre of ground about 50% more trees than light demanders.

The following curve illustrates the interdependence between age and number of trees per acre:



III. Growing space of a tree.

In their early youth all species stand or even desire a dense cover overhead. When the food supply stored in the seed shell is consumed, however, the seedling requires light to digest its food. With increasing age, the tree boles getting longer, the crowns rub and beat one another intensely, swaying pendulum fashion in the wind. As a consequence each crown is surrounded with an air space, the relative width of which depends largely on the length and the flexibility of the bole. It might be stated that the growing space of a tree is a function of the square of the gradually lengthening bole.

Trees differ in the ease with which warring neighbors lose their buds and shoots. Oak, for example, loses its May shoots easily, whilst Beech, struggling with Oak, loses a few leaves only along its flexile swaying twigs. In heavy storms Yellow Pine often loses whole branches. White Pine, on the other hand, does not easily lose its shoots. The top shoots of the taller individuals are immune from harm. Thus a tree, once in the lead of its competitors, has a good chance to retain the lead over them.

IV. Grades of density of cover are: Pressed cover, Close cover, Light cover and Open cover. No strict definition of these terms can be given. Obviously the number of stems under pressed conditions is very large.

Indications of a normal cover are:

a. Relation between length of crown and length of bole.

b. Normal diameter growth and height growth.

c. Proper participation of the various diameter classes in the volume of wood at hand. The normal participation in a pure, even-aged wood is for the

1st. Diameter class—40% of total volume.
2nd. Diameter class—24% of total volume.
3rd. Diameter class—17% of total volume.
4th. Diameter class—12% of total volume.
5th. Diameter class— 7% of total volume.

If cover overhead is too dense, the first class shows over 40% of volume and vice versa.

V. In nature, the same causes necessarily have the same result. The causes of timber production are soil and atmospheric food "falling" onto the soil in the shape of sunshine, moisture and air. Hence, whatever the species are, it seems as if the acre of ground, fully stocked, must produce on the annual average the same weight of timber—not the same volume of timber. Thus, ceteris paribus, species of light specific gravity are the best volume producers. Since, however, shade-bearing species are better digestors of atmospheric and terrestrial food, the largest growth per acre per annum is obtained from shade bearers of light weight (Hemlock, Spruce, Fir, White Pine).

In the virgin forest the annual production of wood fibre is exactly offset by the annual death and decay of wood fibre. The virgin forest is a forest seemingly in economic stagnation.

VI. The sectional area of a tree usually measured chest high (4½ feet above ground), inclusive of bark, is the area of the circle corresponding with the diameter measured chest high.

The sectional area of an acre of forest is the sum total of the sectional areas of the trees standing thereon. It rarely exceeds one-half per cent. of the acreage of the ground, or 218 square feet per acre.

E. Rotation.

Under rotation is understood the number of years which a seedling requires to reach maturity. For a second growth in America, rotations will vary in length from 60 years to 160 years, according to the species and local conditions. During a rotation a wood lot may pass through the cleaning stages, thinning stages, the stage of preparatory cutting, the seed-cutting stage and the stage of final removal.

F. Size classes and age classes.

I. Pinchot adopts the following seven age classes or size classes of trees in his "Primer:"

a. Seedlings, up to 3 feet high.

b. Small saplings, from 3 to 10 feet high.

c. Large saplings, 10 feet high to 4 inches diameter.

d. Small poles, from 4 inches to 8 inches diameter.

e. Large poles, from 8 inches to 12 inches diameter.

f. Standards, from 12 inches to 24 inches diameter.

g. Veterans, over 24 inches diameter.

II. During the sapling stage, the specimens form a thicket; during the pole stage, they form a polewood; and during the standard and veteran stage, a tree forest.

III. During the thinning stage (pole stages) of trees in an even-aged wood, the following classes of mess-mates might be distinguished:

a. After Schlich, "Dominant," "Dominated," "Suppressed, yet alive," and "Dead."

b. After Pinchot, "Dominant," "Retarded," and "Overtopped."

c. The usual classification, adopted by German foresters after Krafft is:

1. Predominating trees, having crown strikingly well developed.

2. Dominating trees, with well-developed crowns, forming the main cover overhead.

3. Condominating trees, with crowns of a fairly normal form, but of somewhat poor vigor, carrying, however, their crowns within the level of the main canopy.

4. Dominated trees with crowns more or less crippled or pressed from the sides, subdivided into two sub-classes, viz.:

a. Most of crown free from cover overhead.

b. Most of crown underneath cover overhead.

5. Trees absolutely suppressed, standing entirely under the cover of others.

G. Even aged woods:

Woods, the components of which differ in age by less than 25 years, are called "even-aged woods."

In America, even-aged woods and hence the advisability of thinning is mighty rare. The struggle for existence between even-aged comrades can readily be alleviated by the forester's interference.

In America, even-aged woods are formed, for instance:

I. By Long Leaf and by Cuban Pine.

II. By Jack Pine and Lodgepole Pine.

III. By Bald Cypress.

IV. By Douglas Fir.

V. By Pinus echinata, taeda, strobus, ponderosa, virginiana on abandoned fields.

H. Distribution of species.

The horizontal distribution of species depends on the latitude and the proximity of the ocean, or better on sea winds, and proceeds parallel with the vertical distribution. In the neighborhood of Biltmore, the following altitudes may be given:

Spruce and Fir—5,500 ft.

Beech—2,000 to 6,000 ft.

Hemlock—2,000 to 3,800 ft.

Chestnut—2,000 to 5,000 ft.

Chestnut Oak—2,000 to 4,000 ft.

Pignut Hickory—3,000 ft.

Bitter-nut Hickory—3,800 ft.

Black Cherry—3,500 to 5,000 ft.

Pinus virginiana—2,000 to 2.500 ft.

Pinus strobus—2,000 to 3,500 ft.

Yellow Poplar—2,000 to 4,000 ft.
Buckeye—3,000 to 6,000 ft.
Red Oak—2,000 to 5,500 ft.
White Oak—2,000 to 5,000 ft.
Spanish Oak—2,000 to 3,800 ft.
Post Oak—2,000 to 3,000 ft.
Black Oak—2,000 to 3,600 ft.
Echinata—2,000 to 2,600 ft.
Rigida—2,000 to 3,500 ft.
Pungens—4,500 ft.
Locust—2,000 to 5,500 ft.
Black Gum—2,000 to 4,000 ft.

Every species thrives best in certain centers, which are few in the case of the exacting and numerous in the case of modest species like yellow Pine, both east and west.

Aside from vertical and horizontal elevation, the influence on distribution exercised by storm, snow and sleet is very marked.

Paragraph VI. Light demanders and shade bearers.

A. A plant is termed the more shade bearing or tolerant of shade, the less light it requires for the functions of assimilation, breathing, perspiration, flowering and fruiting. Only parasites live without light, and hence without chlorophyl.

B. The following characteristics, in their aggregate and not singly, may lead the observer to classify a tree as a shade-bearer:

I. Dense leaf canopy.

II. Leaves thin, dark, flat, more numerous, not glossy, not downy, not bunched at the ends of the branches, with blades spread horizontally, withering quickly after separation from the branch.

III. Thin bark.

IV. Thick sapwood.

V. Branches persistent, spread flat or pointing downward, comparatively thin and interlacing. Crowns long.

VI. Little live soil cover, and a heavy layer of dead humus underneath leaf canopy.

VII. Dense stand of trees.

C. Factors influencing the relative demand for light within one and the same species are:

I. Latitude and hence intensity of insolation.

II. Exposure.

III. Fertility of soil, and hence digestive power.

IV. Age of plants.

V. Distance between the crown levels of the shaded and of the shading trees.

Instances for I and III.

White Pine is, in the south, almost shade bearing; in the north it is almost light demanding.

Yellow Poplar on fertile soil stands heavy shading overhead.

D. Woody species in their relative order of resistance against heavy shading might be arranged as follows:

I. Relative order for the southern Appalachians:

Witch Hazel.
Dogwood.
Fir.
Hemlock.
Hard Maple.
Chinquapin.
Black Gum.
Spruce.
Soft Maple.
White Pine.
Pinus virginiana.
Linden.
Chestnut.
Red Oak.
White Oak.
Chestnut Oak.
Ash.
Spanish Oak.
Black Oak.
Finger Oak.
Post Oak.
Pinus rigida.
Black Locust.
Poplar.
Hickory.
Pinus echinata.
Sassafras.

Unfortunately, at Biltmore, shade bearers are usually weeds interfering with the valuable species.

II. Pinchot gives the following schedule for the Adirondacks:

Hard Maple.
Beech.
Hemlock.

Spruce.
Balsam.
Soft Maple.
Birch.
White Pine (intermediate).
Black Cherry.
Black and White Ash.
Bird Cherry.
Cottonwood.
Tamarack.

The trees above White Pine Pinchot calls "tolerant" and those below White Pine "intolerant of shade."

III. The leading species of the United States, classed according to light or shade-demanding qualities are:

a. Eastern Conifers:

Long Leaf Pine—distinctly intolerant of shade.
Echinata—light demander.
Taeda—intermediate.
Virginiana—intermediate.
Rigida—not so much as virginiana.
Bald Cypress—light demander.
Chamaecyparis spheroidea—shade bearer.
Spruce—fair shade bearer.
Balsam—intense shade bearer.
Hemlock—intense shade bearer.
Tamarack—light demander.
Arbor vitae—shade bearer.
White Pine—intermediate.
Jack Pine—light demanding towards intermediate.
Norway Pine—light demander.

b. Eastern hardwoods:

Beech—shade bearer.
Hard Maple—shade bearer.
Silver Maple—shade bearer.
Red Maple—shade bearer.
Black Gum—shade bearer.
Sourwood—light demander.
Locust—light demander.
Yellow Poplar—light demander.
Chestnut—intermediate.
Oaks—light demanders (White and Red Oak stand lots of shade when young).

Elm—shade bearer.
Birch—light demander or intermediate.
Black walnut—intermediate.
Linden—shade bearer.
Umbrella tree—less light demanding than Yellow Poplar.
Cucumber—less light demanding than Yellow Poplar.
Sycamore—medium shade bearer.
Willows and Cottonwoods—light demanders.
Liquidambar—light demander.
Hickories—light demanders.
c. Western Conifers:
Douglas Fir—intermediate.
Ponderosa—light demander.
Nut Pines—intense light demanders.
Lodgepole Pine—intermediate.
Sugar Pine—intense light demander.
Lawson Cypress—intense shade bearer.
Tide-land Spruce—shade bearer.
Redwood—shade bearer.
Western Hemlock—intense shade bearer.
Western Firs—intense shade bearers.
Larch—intense light demander.
Engelmann's Spruce—shade bearer.
Colorado Blue Spruce—shade bearer.

Paragraph VII. Pure versus mixed woods.

A. Conditions inviting pure woods and mixed woods.

Conifers are more apt to grow in pure forests, owing to their greater modesty. Abroad, up to a very recent time, the desire of the forester was to raise mixed woods, but quite recently the "Danish propaganda" has turned the minds of some foresters back to pure woods.

Severe climatic conditions and poor soil conditions invariably give one species the preponderance, for example: Bald Cypress rules in the swamps of the South, Tamarack in those of the North; Nut Pines prevail in the semi-arid regions of the Southwest; Long Leaf Pine on poor sand in the South; Cuban Pine in half swamps of the South; Red Spruce on the "Black Slopes" of the Adirondacks; White Spruce in Northern Canada; Lodgepole Pines on old burns; Jack Pine on poor sand in the Lake States.

Pure forests are sometimes in the interest of the owner, for example: Pure Spruce near paper mills; Hickory near carriage works; Tan Bark Oak near tanneries.

A high rotation often leads to a pure forest, a short-lived admixture being gradually pressed out.

Abroad the forester is required to maintain the fertility and productiveness of the soil. Since light-demanding species allow the soil to be baked by the sun during the pole and tree stage of the forest when grown purely, admixture of shade bearers under such conditions is advisable, obtained, for instance, by underplanting Yellow Pine with Beech, when Pine is 50 years old.

B. Kinds of mixture.

A mixture may be temporary or permanent; a mixture may be even aged or uneven aged; the species may or may not differ in height growth; the mixture may be composed of single individuals; of strips, rows, bunches, groups; or it may show an irregular character.

In the course of time the original character of the mixture might be changed entirely by the forester or by nature.

C. Advantages of mixtures.

Mixed forests take advantage of differences of soil qualities; the moisture-demanding species gradually claiming the dells and more modest kinds obtaining preponderance on the dry plateaus or spurs.

A mixture may form a preventive against late frost.

A mixture is better protected against damages by fire, insects, fungi, storms, snow, etc.

A mixture produces a better quality of humus (Pine and Oak humus is better than pure Oak humus or pure Pine humus).

A mixture produces a larger quantity of timber for the above reasons in addition to the fact that a mixture allows its components to more fully utilize the productive factors of the air as well as those of the soil through

a. Difference of crown formation, crown levels, crown density.

b. Difference in root system (tap and flat-rooters mixed).

c. Difference in mineral and light requirements.

A mixture also tends to produce cleaner timber—certainly so for the benefit of light demanders when placed in mixture with shade bearers.

For all these reasons a mixed forest may be said to produce a larger and safer revenue than a pure forest.

Valuable species might be raised beyond the limits of their habitat in mixed forests.

D. Objections to mixed forest.

The administrative and the sylvicultural management of mixed woods is more difficult and hence more expensive than that of pure woods.

In America logging expenses are much increased where only one species can be utilized in mixed forests. Logging for Spruce on "Black Spruce Slopes" in the Adirondacks is relatively cheaper per thousand feet board measure than logging for Spruce where Spruce forms only one-third of the growing stock. This objection does not hold good, of course, where all species are marketable at the same time.

E. Rules governing the composition of a mixture and rules for treating mixed forests (holding good for artificial and semi-artificial forests):

I. Species selected for a mixture must improve one another.

II. Each species should occupy that section of ground on which it thrives best.

III. The mixture should at least maintain the productiveness of the soil.

IV. A light-demanding species mixed with a shade bearer must either be given an advance in age or else must naturally possess an advantage in rapidity of height growth; otherwise it soon disappears. This relative height growth is not a fixed quantity; it usually differs according to the soil and to the climate.

V. The denser the forest cover is, the earlier and the more intense must be the help given to the species likely to be suppressed (Sassafras and Locust in mixture with Chestnut).

After Henry Mayr: species which are botanically different from the most natural mixture (Oak and Pine at Biltmore; Birch and Spruce in Balsams; White Pine, Linden and Elm in Michigan). The exceptions to this rule are many (Norway and Jack Pine in Michigan; Red Firs and White Firs in the Pacific Coast States).

Paragraph VIII. Dr. Henry Mayr's (Munich) fundamental principles of Sylviculture.

A. Forest is possible only where the mean temperature of the four months of most active growth averages 50 degrees Faht. or over

B. A mean summer temperature (May to August) of 53 to 59 degrees Faht. produces the Fir and Spruce zone of Europe, Asia and America. A mean summer temperature of 59 to 64 degrees is productive of Beech, also of White Oak, Maple, Hemlock and Chamaecyparis. A knowledge of the summer mean is essential when introducing exotics. A knowledge of the possibilities of forest growth in a given country implies a knowledge of the mean summer temperature.

Some very modest trees are unreliable as indicators or thermometers (i. e. Pinus echinata, Pinus ponderosa).

C. A species may be grown far from its original habitation, provided that the local climate of the new region is analogous to that of the old. If the exotic comes from a warmer climate, it should be placed on south slopes with plenty of sun; if it comes from a colder climate it should be placed in moist soil and on cool aspects. There is no such thing as adaptation of trees to a different climate, or as acclimatization of trees. Walnut, Peach, and Black Locust have been grown in Germany for centuries, because the climate of naturalization was and is essentially identical with that of the natural habitat of the trees.

D. Tree specimens of a cold climate do not possess in themselves any special power of resistance to frost. It is useless to import seeds from colder climates in the hope of obtaining greater hardiness (Douglas Fir from Oregon and from Colorado differ, however, in hardiness).

E. Species of trees growing in hot localities or else in open stands place comparatively small claims on the fertility of the soil. All species bear shade better when brought to a warmer climate and require more light when brought to a colder one (White Pine).

F. In level countries, at not over 500 ft. elevation, the habitation of a species depends on latitude considerably modified by sea winds. In many countries, away from the ocean, that modification is so strong as to create a dependence of the habitation more on longitudes than on latitudes. In high mountain regions, altitude may produce effects similar to those of latitude: it is, therefore, a mistake to label one species as a mountain species and another as a plains' species. In Eastern North America Picea rubens, in Western North America Douglas Fir, also Abies grandis and amabilis, bear witness to this truism.

G. The climatic needs of a species are better characterized by the forest zone than by the latitude or the altitude at which or up to which it grows. Even a knowledge of altitude and latitude combined furnishes insufficient information relative to such climatic needs.

H. If, in a given climatic zone, there are found two neighboring species of the same genus, it is safe to assume that these two species were not mixed originally, but that each had its distinct habitation and that the mixture is due to the action of man.

I. In primitive forests the species which harmonize are those which differ botanically.

J. When two species are so alike as to be almost varieties but have, nevertheless, different climatic needs, then they are, in reality, true and distinct species (Douglas Fir in Colorado and Oregon).

K. Frost injury is always due to the death of the plasmodium killed by the direct action of the frost. The plasmodium is most sensitive during the time of cell formation and of active growth. The plasmodium in the inert stage, as in seeds, is actually insensitive.

L. All species become more hardy as they grow older. This is simply due to the trees rising above the cold layers of temperature near the ground and to the greater thickness and mass of the trunk, resisting rapid changes of temperature.

M. The degree of moisture in the air required for forest growth is 50% relative humidity during the growing season. The broad-leaved trees and the two and three needled Pines are the species best adapted to regions of extreme dryness or of sudden changes in atmospheric moisture.

N. The association of trees into a forest has the effect of increasing the relative humidity by not to exceed 10%. Hence the necessity of maintaining forest in regions where the tension of watery vapor is close to 50%. The partial destruction of a forest may entail the death of the remainder rendering reforestation impossible unless it is started from the nearest adjoining forest. Inside a forest the greater atmospheric humidity acts as beneficially as a moist ocean wind, lacking, however, the latter's violence.

O. It is in moist, cool localities (mountains and northern climate) that climatic variations are the least extreme during the growing season. It is here that the annual rings are equal, the grain fine and regular, and the timber of the greatest commercial utility.

P. The moister the climate, the easier becomes forest culture, and the forester is apt to make the least mistakes in thinnings, regeneration, fellings, etc. Air moisture seems to exercise a favorable influence on the straightness of the stems.

Q. It is known that a failure of rain for several days may be fatal to young plants. The faculty of persistence increases with age, and the grown trees can endure long periods of drought. If, however, the lack of rain is such as to bring the sum total of precipitations during the four months of the growing season below the two-inch mark, then the forest disappears, even if the humidity of the air remains above 50%. Exception—immediate neighborhood of lakes and rivers with their sub-soil percolation.

R. A fairly moist soil is the best for all species in their optimum climate. In hotter places the locality must be more damp, while in colder ones it may be dry without hindering growth (White Pine in the Pink Beds in swamps, in Canada on dry soil; Sitka Spruce in Washington in swamps; in Alaska on dry land).

S. Snow protects those parts of a plant which it covers; it increases the danger, however, for the parts just above the snow level. Snowy winters are, therefore, useful to low plants, but harmful to trees (except broad-leaved trees).

T. As regards the winds, the most dangerous are those which follow the direction of the barometric minima, which in Eastern America travel from east to west; in Europe from west to east; in East Asia from south to north. Next dangerous are the winds traveling in the opposite direction, whilst those from other points of the compass are more harmless. Every mountain, however, creates a deflection of the current and possibly a return in the opposite direction.

U. In their youth trees are almost indifferent to the quality of the soil; with increasing age their exigencies increase. Thus plantations on poor soil may thrive well for a number of years, only to be suddenly arrested at the beginning of the pole stage.

V. In their most suitable situation (natural optimum) a species succeeds on soil of any mineral description. In a less favorable climate the soil requirements of the species increase.

W. The light most favorable to activity of the chlorophyll is not the light of the blazing sun, nor is it the diffused light coming through rain or fog, but that light which is reflected by brilliant white clouds. Leaf cover overhead is favorable when it filters the rays of a burning sun and unfavorable when it excessively reduces the intensity of insolation. Under a continental climate, cloudless days are more numerous than near the coast. The influence of thinnings and removal cuttings on the remaining growth consequently depends on the continental position of a forest—not solely on species and soil.

X. The regeneration of forests approaching exploitable age is easiest in their optimum climate. If the climate is too warm, seed will be more abundant, and the young plants will endure cover better. The moisture of the air, however, is wanting, and the denser cover overhead may intercept too much of the needed rainfall.

If the climate is too cold, the moisture of the air indeed increases; but the production of seeds and the persistence under cover decrease.

Y. In mixed forests artificial regeneration is more difficult than natural regeneration. A clean felling results in a capricious complication of natural laws and phenomena whose contrary actions are not easily understood. Natural regeneration, a mixture of species suitable to the locality, a crop resembling as closely as possible the primitive state, such are the conditions which the forester should seek to realize for the avoidance of dangers as well as for the greatest possible yield of the most valuable produce. No method of treatment harmonizes better with nature's laws than the so-called selection system, when each tree is placed in a condition most favorable to its development, and when no single tree is removed for a purpose other than that of regeneration or improvement of the crop.

CHAPTER II.

THE HIGH FOREST.

Paragraph IX. Genesis of the high forest and its methods.

Wood crops can be started either naturally (from stump shoots, root suckers and self-sown seed) or artificially (by planting seeds, seedlings or cuttings). Forests starting from stump shoots, root-suckers and cuttings are called "coppice forests." Forests starting from seeds or seedlings are termed "high forests."

A. Planting in Europe.

Up to 1830 seed planting only was practiced to start high forests artificially. Since then seedling planting has gradually conquered the European field, especially in the case of Yellow and White Pine, Spruce, Ash, Maple and Larch. Beech and Fir are invariably regenerated abroad from self-sown seed; also Oak in France, while in Germany acorns are usually planted.

no.

B. Advisability of planting in America.

Excepting the case of the prairies and, possibly the case of fields abandoned by farmers in the Eastern States, the idea of artificial propagation of forest crops (by planting) seems preposterous in America. As long as an acre of virgin forest can be bought for a lesser sum of money than is required, in the same locality, for the successful re-forestation of an acre of ground, the chances for a remunerative outcome of planting seem very slim. However, the following points should not be lost sight of:

I. The stumpage prices apt to prevail in America in the year 1960 are likely to equal those now prevailing abroad. Hence the same practice which is now remunerative abroad must prove paying in this country; possibly more paying for the reason that the value of the soil on which the growing crop must yield an annual dividend is abroad about ten times as high as it is in the United States.

II. An expense for taxes and administration is incurred annually by the forest owner, whether the forest ground is kept fully or only partly stocked; hence it seems a remunerative venture to—at least—reinforce natural regeneration by artificial planting.

III. The growth of weeds naturally plentiful in primeval conditions cannot be overcome unless radical artificial remedies are adopted.

C. On the other hand, the following objections to planting must be considered:

I.As long as the American forest is much endangered by fire, it is unwise to invest any money in young growth for which the danger of destruction by fire is excessive.

II. Trees of a condition now considered "weeds" may gradually attain a stumpage value (as Chestnut at Biltmore).

III. Even European forestry is now reverting to a natural propagation of forests owing to the dangers usually inherent to artificial planting.

D. Definitions.

The word reforestation is used if the area to be planted has been previously occupied by tree growth.

The word afforestation is used if there was no tree growth on the plot for a number of years beforehand.

Paragraph X. The Seed.

The quality of seeds is shown by their size, weight, color, scent. A tree standing in an open position, not too young and not too old, produces the best seeds.

A. Seed years:

The atmospheric conditions of the year or years during which the seed is formed further influence the quality of the seed. Drought in summer and early frosts in fall cause the seeds to drop immature. Black Oaks and Pines require two years for the formation of seeds. Juniper three years. It seems as if all trees require a number of years for the preparation of seeds, inasmuch as the medullary rays before a seed year are found full of starch, and after a seed year devoid of starch. This phenomenon may explain the periodical occurrence of seed years in Bamboo and Canebrakes, in Chestnut, Oak, Beech, Pine, etc.

The length of the period elapsing between seed years depends on the local climate and the position of the trees, being short for trees standing in orchard-like positions on warm and sheltered ground where abundant heat allows of the rapid accumulation of starch.

B. Rest:

After dropping from the tree, all seeds undergo a period of rest in our climate. This rest is very short in the case of Cottonwood, Willow, Elm and Soft Maple. In the majority of cases, in Eastern North America, it lasts from November to April. In rare cases (German Ash, German Linden, Red Cedar, Hornbeam) the period of inactivity covers about seventeen months. Seeds which get too dry while stored, often show a prolonged period of rest. For White Oak seed the period of rest is only two months; for Red Oak five months. The assumption that frost is required during the resting period for the benefit of the seed is erroneous. The germinating percentage is greatest immediately at the conclusion of the period of rest.

C. Tests:

Germinating tests are made with from 50 to 200 grains.

I. Water test applicable to large seeds. Thrown in water the good seeds will sink, and the bad seeds will float.

II. Cutting tests, made with a knife, used for testing acorns, chestnuts, nuts of Nutpines, also seeds of Ash, Yellow Poplar, Beech, etc.

III. Hot-pan tests for conifers, which causes good seeds to jump and burst, poor seeds to burn and char.

IV. Pot tests made in the following manner: Fill the lower half of a flower pot with sawdust, the upper half with sand in which the seeds are embedded. Place the pot in a basin partially filled with water, in a warm room.

V. Flannel test: Place the seeds between two strips of flannel kept moist by running their ends into a bowl of water standing at a lower level.

VI. Test in the commercial-test apparatus, which consists of a bottom plate (glass or china), a bell-shaped top (same material) and a clay disk containing 100 small grooves, which fits into the bottom plate. All three parts are open in the center. The clay disk is burned in such a way as to retain good hygroscopic qualities, and is boiled for a number of hours (in water) before using, to kill adherent spores of fungi. Moist sand is kept between the disk and the bottom plate. The grains are inserted into the grooves.

Paragraph XI. Preparations for planting seed on open ground.

The germinating bed must offer the seed a proper, constant and equal supply of heat, oxygen and moisture. The actual amount of heat, oxygen and moisture required has not been ascertained scientifically. Observation in the woods is the best teacher of the conditions securing the largest possible germinating percentage for any given species.

The preparation for seed-planting may extend over the entire area to be planted; or only over certain strips which may be interrupted or continuous; or it may merely involve the grubbing of plots or spots. Where the ravages of game or mice are feared, irregular working is advisable.

A. Removing the soil covers, such as briars, Kalmia, Chinquapin, mosses, dead leaves, humus. A plow and grubber (cultivator) or a harrow can usually not be used for the purpose; the hoe (a strong make) is largely used abroad; weeds are removed with brush hooks or scythes or machetes or are, if possible, killed by deadening. In certain cases an iron rake might do. Often it is necessary to remove the cover by fire; fire, however, produces a heavy growth of weeds on fertile soil (as in Pisgah forest).

B. Loosening the soil. Just after logging, the soil has enough porosity to allow of the development of a second growth. On abandoned fields or in prairies thorough working with the plow, often continued for a number of years, may or must precede the act of planting.

Paragraph XII. Securing and preparing the seeds.

A. European tree seeds are usually bought from reliable dealers, who rival in furnishing the best seed at the lowest price, guaranteeing a certain percentage to germinate. In America, the forester must secure seeds himself, collecting them by contract, or preferably, by day work. Some European sylviculturists insist that seeds should be taken only from the best and strongest trees. Mayr considers special care superfluous.

B. Under "coning" is understood the method of obtaining seeds of coniferous species from their cones. Coning of Spruce, Pine, Fir and Larch on a commercial scale is practiced in Europe by Henry Keller, Appel & Co. and A. Lecoq, all of Darmstadt, Germany.

Certain Pine species (Nutpines) have wingless seeds. The wings of other Pine seeds hold the grain in a claw.

The seed of Spruce lies in the wing as in a spoon; the seed of Larch and Fir is attached to the wing and is not easily separated.

Among the broad-leaf cone bearers—Alders, Birches and Magnolias—the coning of Magnolias only offers some difficulties.

I. The methods of coning are as follows:

a. Coning by insolation, the oldest and safest method. Trays, the bottoms of which contain open lath work or wire netting, are placed in the sun and removed to a shed if rain threatens to fall. The cones are spread on the trays in layers not over two cones deep and are stirred with a rake. In place of trays, drums might be used to good advantage. In a cold climate the sun process allows of obtaining the seeds only at a time too late for seed planting. The germinating percentage of seeds obtained by the sun process is, otherwise, superior to that of seeds coned by other methods.

b. Coning by stove heat.

It is essential that the heat in the coning room should not reach 110 degrees. Thorough ventilation is required to prevent sweating and moulding of cones. The cones are spread in the coning-room in thin layers on shelves or screens, through the interstices of which the seeds drop. The cones are stirred three or four times a day.

It is unwise to have the stove in the coning-room. An American hot-air furnace in the basement is well adapted to furnish the heat.

Many of the large European forestry administrations have such or similar establishments for coning.

c. Commercial method.

In the commercial establishments, heat is supplied by steam pipes, controlled by automatic devices. The trays or drums are kept in a constant rocking motion by machinery. The seeds, after falling through the crevices of the trays, are at once conducted to a cool room.

II. Separating seeds from their wings.

In the case of Pine and Spruce seeds, flailing is sufficient. It is not advisable to wet the seeds before flailing. For Larch, rubber millstones are used, the distance between the stones being equal to the smallest diameter of the seed.

III. Cleaning the seed from dust, needles and wings. The seeds are freed from admixtures by fanning, shoveling, centrifuge or any grain-cleaning machine. The large commercial establishments drop the seeds on endless rolls of cloth, which are moving on an incline. The heavy seeds slide down, whilst dust and wings are carried uphill.

IV. Statistical notes.

a. Spruce in the Adirondacks (after Clifford R. Pettis).

1. Cost of picking cones 50c per bushel (green).

2. One bushel of green cones yields two bushels of dry cones, containing 1⅞ lbs. equal to 1½ qts. of Spruce seeds.

3. One bushel of cones weighs 60 lbs., one bushel of seeds 40 lbs.

4. One pound of seed contains 150,000 grains.

5. It costs 95c to collect, cone and clean one pound of seeds.

b. White Pine at Biltmore.

1. 100 bushels of cones will weigh 2,200 lbs. (a "long ton").

2. One bushel contains 600 to 700 cones, and yields, on an average, ½ lb. of absolutely clean, wingless seeds.

3. One pound of such seed contains 25,000 to 30,000 grains.

c. Yellow Pine (ponderosa) in New Mexico (after Wm. H. Mast).

1. One bushel of cones yields 1.55 lbs. of clean seed.

2. The expense of collecting, coning and cleaning averages 23c per pound.

d. Colorado Blue Spruce in New Mexico (after Wm. H. Mast).

1. One bushel of cones yields 1.2 lbs. of clean seeds.

2. The expense of coning, collecting and cleaning averages 23c per pound.

e. Shortleaf Pine at Biltmore (Pinus echinata).

One bushel of cones yields one pound of clean, wingless seeds at an expense of $1.00 per pound.

C. Seeds stored beyond the duration of their natural period of rest show a reduced percentage of germination. The percentage might be increased by the use of slightly acid solutions, lime water or hot water. Coniferous seeds are often placed in cold water for from three to seven days previous to planting; seeds thus treated, however, must be supplied with moisture artificially after planting if drought sets in.

D. The "malting" of seeds (placing the seeds in heaps, moistening them and stirring them in a warm room) is a rather dangerous procedure. After Weise, Douglas Fir and White Pine seeds should be mixed with moist and fertile soil and stable manure, to be then exposed to a hot-house temperature until the germs begin to show. S. B. Green recommends to pour boiling water on the seeds of Locust, Honey-Locust and Coffee-tree, and to allow the seeds to remain in the water until it is cold, planting immediately thereafter.

Paragraph XIII. Actual planting of seeds on open ground.

Seeds should not be planted on rainy days, especially not on clay soil. For broadcast planting, the area to be planted and the seed are divided into equal lots. The quantity of seed allotted to the unit of space is subdivided into halves. Each half is sown separately by going over the ground crosswise.

Broadcast planting is rare nowadays.

Rough nursery beds (either running full length of the area or interrupted beds), furrows or banks are frequently provided. Narrow trenches may be pressed into the beds or banks with the help of a board, a hoe handle or a wheel.

The seed is usually sown by hand, possibly with the help of a beer bottle, a so-called seed horn and, rarely, with a seed-planting machine. The machine should only be used on ground as well prepared as a wheat field (prairies or abandoned fields). On land newly cleared, roots and stumps prevent the use of a machine.

"Covering" purports to place or rather press the seeds into contact with the mineral soil on all sides; to prevent sudden changes of air temperature from striking the seed; to prevent the seeds from drying out under excessive exposure to the air. The cover must be such as to allow a young germ to push its cotyledons easily through the cover. The seeds keeping their cotyledons below ground (Oaks, Sassafras, Chestnut) allow of a heavy cover.

In the case of coniferous seeds, a proper cover is secured with the rake or with a brush drag; or by marching the planters, a band of sheep or a herd of cattle over the plantation. Heavy seeds are often strewn on the ground without any preparation and then covered with a shovelful of dirt. In America seed-planting in the open is an unadvisable measure as long as the prices of seeds maintain their present figure.

"Planting of cones" was the leading method used a hundred years ago by European foresters. The cones were strewn on the ground and stirred periodically by sheep, with good results.

Seeds more than one-quarter inch thick, especially nuts, are usually dibbled with dibbling hammer, wedge, knife, hoe, spade, etc. The hole made should place the seed at the best depth. The hole is closed by side pressure, by the foot or the hammer, or by allowing a lifted sod to drop back in place. The common planting spade often puts the seeds too deep.

A. The quantity of seeds used per acre depends on:

Price of seed.

Density of stand desired.

Tenderness, sensitiveness and rate of growth of species.

Local damage from late frost, drought, weeds, insects, mice, squirrels, rabbits, game, birds, etc.

Quality of both soil and seeds.

Fineness of prepared soil.

Method of planting by hand or machine, regular or irregular, broadcast or in patchwork. Planting seeds in bands or strips only requires two-thirds or three-fourths of broadcast amount; planting in patches one-half, in holes one-fourth of the same.

B. Figures adopted at Biltmore for broadcast planting are, per acre:

White Oak and Chestnut Oak, 12 bu.

Red Oak and Black Oak, 8 bu.

Ash, 40 lbs.

Beech, 130 lbs.

Maple, 40 lbs.

Elm, 24 lbs.
Birch, 32 lbs.
Firs, 45 lbs.
Spruce, 10 lbs.
Larch, 10 lbs.
Yellow Pine, 8 lbs.
White Pine, 12 lbs.

C. Small seeds: Number of seeds in one pound (approximately, all coniferous seeds without wings):

Ash	6,200
Elm	55,000
Silver Fir	9,000
Tamarack	70,000
White Pine	30,000
Maple	[illegible]
Birch	[illegible]
Spruce	[illegible],000
Yellow Pine	[illegible]0,000

D. Large seeds: Number of se[illegible] bushel are: White Oak, 8,000; Red Oak, 3,000; Walnuts, 800.

Paragraph XIV. Season for seed planting on open ground.

For Cottonwoods, Elms (excepting Red or Slippery Elm), Soft Maple, Black Birch and Mulberry, the best time of planting is nature's time,—immediately after the fall of the seeds—in early summer. In the case of the species enumerated, the period of rest is very short and the seedlings starting rapidly have time to lignify before winter. In all other cases the forester can plant either in fall or in spring. Planting in winter is usually prevented by the condition of the soil.

A. Planting in fall invites:

I. Inroads of animals in winter.

II. Washing of seed when snow melts.

III. Damage from late frost, since planted seeds sprout early in spring.

B. Spring planting necessitates:

I. Expense for seed storage over winter.

II. Checks during storage, injurious to germinating percentage.

III. Higher expense for planting, planting taking place at a time when labor is scarce.

Spring planting forms the rule, except with Fir, Beech, Chestnut, White Oak.

In semi-tropical regions or places of periodical drought, the best planting time is the fortnight preceding the rainy period. On dry soil seeds are planted as early in spring as possible so as to profit from the moisture left by melting snow.

Seeds which naturally germinate 18 months after maturity (Red Cedar, Hornbeam, some Ashes, some Basswoods) require stratification: Place seeds, in dry soil, in a ditch ten inches deep and ten inches wide, to a depth of five inches. Cover seeds with straw and dry weeds, and finally with dirt. After the lapse of a year the seeds are ready for planting.

Paragraph XV. Auxiliaries to seed planting.

A. Means to protect species needing shade in earliest youth.

I. Plant seeds with oats, barley or summer rye, planting the grain seed in quantities not to exceed 75% of the normal. Cut grain crops high. This method was used regularly 100 years ago, for European Pine and White Oak, possibly with a view to early returns, possibly to distract ravages of field mice and birds.

II. Certain species, tender and shade demanding in early youth like Beech and Fir, cannot well be raised in the open, unless an usher growth 12 to 15 years older (of Yellow Pine, Sassafras, Black Locust, Birch) is previously started on the ground. The usher growth is gradually removed when the seedlings underneath want "skylight." In semi-arid parts such usher growth is perhaps doubly advisable; further in prairies, where Poplars and Willows, Box Elders and Soft Maple might serve as ushers (also Locust).

B. Means to protect the seed plantation from animals and weeds.

I. Against seed-eating animals. Planting in late spring offers some protection. Planting in sprouting condition protects heavy seeds from rodents; slight coating of red lead protects conifers from birds. A watchman might be kept on large plantations, to scare the birds away. By coating large seeds with tar, crows might be kept away.

II. Light cover of weeds is no disadvantage. Where weeds are heavy, seedlings should be planted, rather than seeds. Mowing (with scythe) weeds and ferns, crushing briars—preferably before weeds are seeding—is recommended. Where seeds are planted in rows or furrows on abandoned fields, cultivation checks weeds.

III. Pasture is not allowed in seed plantations before the thicket stage is past.

C. Reinforcing. Bare spots where seed planting has failed are usually reinforced by planted seedlings. The latter are taken from adjoining dense spots. In broad-leaved species, the blanks where planting has failed, had better be marked during the preceding summer.

Paragraph XVI. Planting seeds of the broad-leaved species.

A. Acorns.

The germinating acorn leaves the cotyledons below ground. If the first shoot is killed another forms at once. A shelter (or usher) growth to husband a plantation during its first years is hardly needed. Still plantations of Yellow Pine made to protect the Oaks planted between the Pines are often found abroad. Its long tap root prevents the Oak from being lifted by frost.

The soil cover given varies between one and three inches, according to the looseness and porosity of the soil. In case of spring sowing, germination requires from five to six weeks.

At Biltmore, White Oak and Chestnut Oak acorns planted in fall are often found sprouting before Christmas. The germ in such cases, however, does not appear above the ground. Red Oak and Black Oak seem to sprout only in spring. Acorns may be sown broadcast, especially on abandoned fields. Formerly acorns were planted often with oats and barley or summer rye. The cover is given with a harrow in case of broadcast planting.

More often acorns are planted in furrows from two to seven feet apart. It is better to plant acorns closely within furrows far apart, than sparingly in furrows near together. The cover is given either by a second furrow or by hoe or rake.

Cultivation between rows (during summer) is not practiced abroad. On abandoned fields at Biltmore it seems required for the purpose of checking mice, squirrels and rabbits.

Where acorns are planted for mixture merely with Beech, Pine and Chestnut, the planting in irregular patches or else "oversoiling" are often used. In the latter case a handful of acorns is roughly covered by a shovelful of dirt.

The usual method adopted abroad for raising Oak is dibbling.

The answer to the question whether spring or fall planting is better, depends on the number of enemies preying on the acorns in winter. Since the Black Oaks are not much molested, it might be as well to plant them in fall. Black Oaks suffer little in germinating percentage during winter storage. White Oak acorns, however, are much eaten by mice, squirrels, turkeys, hogs, etc., and would be planted in spring if winter storage did not invite a large loss of germinating percentage. For wintering White Oak acorns, it is best to place them (imitating nature) in slight layers under a cover of humus on fairly dry soil. After Charles Heyer: Large baskets are roughly made on dry soil, the bottom and walls lined with moss; within are placed alternate layers of moss or sand and acorns. The basket is roofed with straw.

After Von Alemann: Ditches 8 feet wide by 10 inches deep are made on dry soil. The acorns must not be too wet when put into the ditch. The cover consists of a layer of vegetable matter. A rough hut is made all over the ditch, out of slabs, bark, twigs, etc. The acorns are stirred up twice a week during winter. Heyer's method also requires a steep-walled ditch around the place of storage to keep mice out. Possibly it might be wise to keep sacked acorns submerged in running water.

B. Chestnuts.

Chestnuts require more fertile and hence better-prepared soil than acorns. The nut has still more enemies than the White Oak acorn. Its germinating power is much reduced by dry storage over winter. The devices for storing acorns might be used as well for chestnuts. Possibly storage in the husk is preferable. At Biltmore planting of Chestnut on abandoned fields is very unsuccessful, owing to enemies and poorness of soil. But abandoned fields in Pisgah Forest often show fair growth of chestnut—on better soil, especially on moister soil. No experience is at hand relative to nut-plantations on good land newly cut over. Chestnuts dibbled in at Biltmore to form a lower story beneath Yellow Pine are always eaten by squirrels.

C. Walnuts.

Walnuts, both Black and White, can be held over winter like potatoes, without loss. Yet fall planting is better where squirrels do not endanger the nuts.

Walnut has done well planted in furrows on abandoned fields at Biltmore where soil was good, without cultivation; on poor soil the weeds are choking it to death. The dibbling of walnut into woods just cut over has been badly handicapped in Biltmore and Pisgah Forest by squirrels. Otherwise dibbling is the best method in the woods. Possibly the attacks of squirrels might be prevented by late-spring dibbling of nuts in sprouting condition.

D. Birch.

Birch seeds are very small, two-winged. European price for Betula lenta, lutea and nigra, $2.50 per lb.; for Betula papyrifera, 62c per lb.; for European White Birch (Betula alba), 8c per lb. Germinating percentage is bad, especially if seeds are not kept in loose storage. The soil requires little preparation for seed planting. A heavy layer of humus must be removed. Seed can be planted any time from fall to spring. The old foresters used to plant the seed on the snow,—so as to have the seeds washed into the soil by melting snow.

The southern Birches, being solitary, might be planted in irregular patches or trenches, or in places where the mineral soil is exposed by the fall of trees whirled out of the ground with stumps and roots. European Birch is very modest, thriving well on dry soil.

The seedlings are very hardy. They suffer, however, from weeds, grass or leaves blown over them and depriving them of air and sunlight. Betula lenta, at Biltmore, is apt to "damp off."

E. Beech.

Nuts appear every three to seven years in the woods. The nuts ripening in October had better be planted at once after ripening, though much endangered in winter by mice. Storage over winter, possible as in White Oak acorns, requires still more care. If spring planting is resorted to, nuts germinate within five or six weeks. Beech seedlings must have a shelter growth, and cannot survive in the open (excepting moist mountain slopes). The preparation of soil is made with hoe or spade roughly, to a depth of three inches. Abroad, Beech is often used for an undergrowth in pole woods of Pine, Oak, Tamarack, Ash, etc., with a view to improving the humus and, indirectly, the boles of the trees forming the upper story. "Beech is the mother of the soil," because it furnishes the best humus. Beech is exacting; it requires strong and moist soil. Pure forests of Beech are found at Biltmore at 6,000 feet elevation; and extensively in Swain country at 4,000-4,500 feet, with Poplars as standards in an upper story. The price of German Beechnuts is two pounds for five cents.

F. Alders.

The western Alder, Alnus Oregona, and the European Alder are valuable, while the eastern Alder is only a shrub lining the creeks. European Alder is invaluable as a swamp tree and for plantations on very binding soil (clay pits). The seed of the European species is worth 10 cents per pound. Seeds ripen in October and are best kept over winter in the cones. The small seedling is not sensitive to heat and cold, but suffers under the heavy grass usually found in swamps. Since swamps are inaccessible in early spring,—planting of seedlings is preferable to planting of seeds.

G. Ash.

Seeds are abundant, showing about 70% germination. The seedling, in the first year, develops to a length of eight or ten inches, from seeds covered with three-eighths inches of dirt. Little preparation of soil is needed. During the first two years, on good soil, a heavy shelter overhead is easily borne. American White Ash may be grown in slightly swampy soil, or soil subject to long inundations. Prices of Ash seeds: European Ash, 4c per pound; White Ash, 25c per pound.

At Biltmore, White Ash seeds planted in rows six feet apart, on abandoned fields, have done well when soil cover was not too heavy.

H. Maple.

Hard Maple seeds ripen in September. Silver and Red Maple seeds in June. It is wise to plant the seeds just when ripe, especially American species. Price of seeds: Acer rubrum, $3.00 per pound; Silver Maple, $1.00 per pound; European species, 4c to 5c per pound; Sugar Maple, 80c per pound. The green germ of American Maples is said to die if the seeds are not at once planted. Soft Maples develop the seedling in the year of the seed. For seeds to be planted in woods, the soil is prepared with the rake, and the seeds covered with one-half inch of soil. Maple planted on abandoned fields on Northern slopes, well watered and well drained, is likely to be successful. The young seedlings are sensitive, and a cover overhead is advisable, where late frost prevails. On rocky soil in Northern coves, Maple seed is often strewn on the rocks, the rain being expected to wash the seeds into the crevices. At Biltmore, Hard Maple is found only at elevations exceeding 3,500 feet. Sugar Maple is more exacting (in soil) than Soft Maple. It does not grow as well in swampy soil as Soft or Red Maple. Acer negundo (Ash Leaf Maple) does very well in the northern prairies. Seeds ripen in fall.

I. Elms.

Seeds flat, roundish, winged, the wing surrounding the seeds. Seeds, ripening in June, must be planted at once, since they cannot be kept in dry storage (except Slippery Elm—pubescens). Germinating percentage is always small. Elms require such good soil that they can be raised only on strong, northern, moist soil of agricultural value. Never planted broadcast; in suitable localities, seed might be planted in patches on soil roughly prepared with rake. Very little cover must be given.

Seeds cost: Ulmus americana 22c per pound. Ulmus campestris 6c per pound.

J. Buckeye.

The Asiatic species is valuable in deer parks, its fruit being eaten by deer and boar. The American species are poisonous (flava and glabra). Seeds ripen in October, winter well, but can as well be planted in fall. After Weise, the seeds should be planted with the navel down. First class soil (Ohio) is required, or at Biltmore strong North coves at higher altitudes, where Buckeye is sometimes found in small groves. Planted in furrows on abandoned fields (Biltmore), Buckeye has shown rapid progress during the first year, but has since made small shoots only. Seeds of the Asiatic species cost 2¼c per pound.

K. Black Locust.

The seeds ripen in fall and are easily kept over winter uninjured by mice, birds or insects. To prevent seeds from lying over, S. B. Green advises to pour boiling water over them just before planting, a treatment causing many seeds to sprout at once. The fleshy, oval cotyledons and the primordial leaves are not pinnate. The tree is an exception to the rule of optimum depth of covering (the depth of long diameter of seed) since it does best when covered 2 to 3 inches deep. The seedlings are sensitive to late frosts. The planting had better be delayed until the danger of frost is past. The price of seeds, 5-10c per pound, renders Locust seeds the cheapest seed obtainable since the germinating percentage is high. The seedlings grow until late fall, when they reach nearly two feet in height. At Biltmore, Black Locust is planted into Oak coppice on raked patches, with the rake, and on abandoned fields in furrows 5 to 6 feet apart. Five pounds per acre is enough. Plantations suffer from ground mice and, later on, from a moth. Locust thrives on exhausted agricultural soil and is used in Europe exclusively to reforest the Hungarian prairies; further along railroad cuts. Forest-grown Locust is much superior to field-grown Locust.

L. Hickories.

The nuts of the thin-shelled species (ovata and minima) cannot be held over winter and need fall planting. Seed plantations suffer from mice and squirrels, and especially from voles, which bite off the seedlings below ground, row after row. Bitternut seems exempt from such attacks. The seedling, in the first years, spends all its energy in developing a large tap root. The plantations at Biltmore made in furrows on abandoned fields might have been better, had they been cultivated continuously to check the mice and voles. Hickoria ovata, 13c per pound; Bitternut, Pignut or Mockernut, 15c per pound. Hickory needs fertile, fresh soil; the "Hickory flats" in virgin forest are convertible into superior farm land.

M. Linden or Basswood.

Seeds falling in early fall are always poor. The ripe seed (in bunches, attached to wingbracts) falls in late fall or winter. Linden is very exacting and pure woods are very rare. Planted in the forest, it serves only as an admixture. Seeds are planted in spring on soil roughly prepared with rake or hoe. The cotyledon is typically five-pronged, hand shaped. The young plant is so sensitive that cover overhead is strongly advisable.

N. Cucumber tree.

Seeds ripening in cones late in fall are removed with great trouble by hand. Many seeds lie over. The seedling develops on good soil a very long and strong shaft. For forest planting, Cucumber is used only in patches, mixed with Chestnut and Yellow Poplar.

O. Yellow Poplar or Tulip Tree.

Seeds appear annually; of very low germinating percentage. Nature plants the seed between October and May, slowly dismembering the cone. Seeds may be planted in spring after loose storage. The cones are apt to heat and mould, if tightly packed. The cotyledons (size of a nickel) do not show the typical lack of the tip of the leaf blade. They drop off (in strong seedlings) before July 15th. Seedlings do not suffer from mice. Heavy rains, however, are apt to wash them out of the ground. The young seedling stands a good deal of shade. If deprived of light entirely, it is certain to be killed by the first frost. Seeds cost 15c per pound. Large quantities are required for planting, say 50 pounds per acre. Plantations at Biltmore were utter failures, probably owing to poor seed. The seedling grows very fast when young; at the age of two years the seedling is three feet high, on good soil. Where planted in the woods it is necessary to check the weeds, especially on north slopes.

P. Sassafras.

It might be planted on poor abandoned fields as usher growth. At Biltmore, seeds gathered in late summer have failed to sprout, whether planted in fall or spring. The fleshy cotyledon is kept below ground at a depth of say one and one-half inches. Possibly, the seed must pass through a bird before it can sprout, or the flesh must be peeled off by hand or by malting.

Q. Black Cherry.

Primeval trees are found only on fairly rich soil. The Cherry, however, can be easily raised on abandoned fields not better than those at Biltmore. During early youth, until pole stage, mice and rabbits peel the bark badly. The end of the annual shoot is almost always killed in winter. The small purple fruits ripening in early autumn are eagerly eaten by birds. The seeds, after passing through the bird, are scattered all over the woods. The seeds are easily kept in winter, but lie over if kept in a dry condition. A hot-water bath before planting might cause the seeds to germinate simultaneously. In woods, Cherry should be planted under one-half inch dirt cover, irregularly, with full enjoyment of light. Seed 50c per pound. The seeds might be planted in rows on abandoned fields more cheaply than the seedlings.

R. Black Gum.

Nyssa sylvatica has never been raised on a large scale, owing to the low value of its timber. As an undergrowth or admixture with Hickory, Ash, Oak, etc., it might prove, however, a valuable tree, owing to its dense leaf canopy and owing to its shade-bearing qualities. The seeds, cherry-like, dark blue in fall, of acid taste, seem to appear annually, and old trees are often surrounded by an abundance of seedlings; the latter, very light colored, are four inches high by July, showing two heavy oval entire cotyledons, whilst the primordial leaves show the proper form. Seedlings do not seem to suffer from frost, heat or animals. On abandoned fields, however, Black Gum seems to come up from sprouts and not from seeds. The seed is not on the market.

Paragraph XVII. Planting seeds of the coniferous species.

A. Firs.

Very intensive shade-bearers, the Firs cannot be raised without shelter overhead. The young seedling suffers much from frost and heat. Its six to ten cotyledons show two white stripes on the upper side. The young plant is apt to die from leaves smothering it. Its height growth, to the seventh year, is small whilst the seedling tries to establish a root system and to cover its growing space by long side branches. Fir is usually planted in irregular patches as an admixture, moss and mould being raked away. The seeds losing vitality quickly when winter-stored (unless stored in the cones) are usually planted in the fall, in spite of impending ravages of mice and birds. The covering is from one-fifth to one-third of an inch. Since the cones begin to dissolve in November, they must be gathered in early winter. Abies concolor, $3.00 per pound; Abies fraseri, $3.50 per pound; Abies amabilis, $4.50 per pound; Abies balsamea, $1.00 per pound; Abies grandis, $3.00 per pound; Abies magnifica, $5.00 per pound; Abies nobilis, $2.00 per pound; Abies pectinata, 5c per pound.

B. Spruce.

Seeds ripen in the year of the flower and are emitted from the cones, becoming pendulous, between November and April. The seeds are easily wintered either within or without the cones; after some authors, preferably in the cones. Seed years occur at intervals of about five years. The germinating percentage is high. The seeds are usually planted late in spring after bird migration, either broadcast on ground roughly raked, or more often on interrupted beds from one to two feet wide, prepared with hoe and slightly raised over the general ground level. It is said that a man can plant one acre of ground in eight hours, using the rake. Previous to planting it is wise to moisten the seeds in cold water for from three to five days, especially if the seeds are planted in late spring. The cover should be one-fifth inch. Germination takes place after four weeks with from six to eight cotyledons, serrate on the upper side. Young plants are sensitive to drought and readily raised by the frost. Spruce suffers from suppression by weeds and leaves. Its height growth is more rapid than that of Fir. Prices of seeds: Picea canadensis, $1.10; excelsa, 13c; engelmanni, $5.50; rubens, $4.25; pungens, $5.00; sitkaensis, $5.50 per pound.

C. Yellow Pines.

On dry sandy soil, it is wise to plant in early spring, so as to find a moister seed bed. The young seedlings do not suffer from late frosts and are not apt to be lifted by winter frost. The removal of stumps stops the attacks of stump breeding bark beetles and snout beetles (weavils). Intensive loosening of the soil invites the attacks of junebugs, wire worms, etc., and is not needed on sandy soil. Broadcast planting is advisable on soil slightly covered with grass; the cover should just be scratched with the harrow. The seed, unless planted with the rake, is embedded in the soil by driving sheep, cattle and hogs over it. Before planting it might be wise to fire the ground, notably so in the case of Jack Pine, Lodgepole Pine and Norway Pine. Yellow Pine is never planted in patches, since it comes up in larger groups only, of even age. Planted under shelter it would not obtain enough sunlight. The seeds are often planted on long strips two or three feet wide, separated by trenches, the weeds and dirt removed from the trenches being heaped on the strips. On the very driest soil, Jack and Red Pine will do in the north; in the south, Long Leaf Pine. The moisture demands of Pinus taeda exceed those of Pinus mitis. Wet ground is required by Cuban Pine. Pinus ponderosa may grow on any soil and aspect, north and south. European Pine should not be tried in places where snowfall is heavy. The sand dunes at San Francisco are planted in Monterey Pine. A method much used abroad some 80 years ago was the planting of Pine cones (eight bushels of cones per acre). The cones were moved from time to time by a brush drag. Another old method for raising Pine consisted in planting the seeds on top of oats, barley or summer rye. The cover given should be one-fifth of an inch. The seeds are mulched for three to seven days, before planting, in cold water. Old seeds are apt to lie over for a whole year. Germination occurs in from three to four weeks. The first leaves stand singly, and not in sheathed bunches. The primordial leaves are strongly serrate. The germinating percentage is high, say seventy to ninety per cent. The seedlings of Pinus rigida creep on the ground the first two years as if dwarfed. Prices: banksiana, $5.00; murrayana, $10.00; inops or virginiana, $1.10; jeffreyi, $4.00; mitis, $10.00; ponderosa, $2.50; pungens, $4.50; resinosa, $9.00; rigida, $2.50; European Scotch Pine, 50c; tuberculata, $4.50; taeda, $10.00; palustris, $4.50 per pound. In Jack Pine, Lodgepole Pine and Table Mountain Pine the seed is not emitted for a number of years from mature cones. At Biltmore, mitis drops the seed between November 1 and December 15; Palustris seeds seem to drop before December 15, since seedlings appear by middle of January.

D. White Pine.

White Pine seeds cannot be kept as easily over winter as Yellow Pine seeds. The seed matures at Biltmore about September 15, and then falls at once. The European recipe, to gather the seeds when drops of rosin appear on the cones, is misleading. After gathering, the cones should be fully matured by exposure to sunlight. Cones placed in heavy layers—over six inches—after gathering are apt to mould, when the seeds will be destroyed. White Pine emits seeds easily, placed in light layers on wire netting, when heat is applied, and when the cones are stirred several times a day. The rooms in which the coning takes place must be well ventilated. Seed years occur in the South every three years—in the North say every seven years. Mulching before planting is absolutely necessary. Germination after three to four weeks: seven to ten cotyledons, primordial leaves singly. Seedlings suffer still more from fungi (honey fungus) than Yellow Pines. Owing to the high price of seeds of White Pine, the seed is usually planted in nurseries only. An experiment at Biltmore, namely planting of seed without preceding preparation of soil in patches with the rake, under light cover, has proved a failure. White Pine does well on abandoned fields after fires—except on East and Southeast slopes where flat-rooted plants are apt to be lifted by frost. Germinating percentage only from forty to fifty per cent. Seeds cost about $1.50 per pound.

E. Hemlock.

Seeds mature toward the end of September, are very small and easily removable. Seedlings are very shade bearing and minute. Hemlock cannot be grown in the open. Price of seed being high and natural regeneration being easy, plantations will not be made on a large scale. Price of seeds: canadensis, $3.50; heterophylla, $8.00; mertensiana, $5.50 per pound.

F. Larch.

The cones are very tough and not easily opened by heat. It is hard to separate the wing from the seed. The germinating percentage is low. The seed is planted in spring on open ground, usually in patches, mixed with Pines, Spruces or Hardwoods. The planting of seed of Northern Tamarack in Northern swamps is out of the question. The height growth in early youth is rapid. Larch puts heavy demand on light. Cotyledons, five to seven in number, appear four weeks after planting. The seeds are mulched in cold water for at least a week before planting. The primordial leaves stand singly; brachyblasts are formed only from the third summer on. Young shoots never show brachyblasts, but needles only. Price of seeds: European Larch 50c per pound; Japanese Larch (leptolepis) $2.50 per pound.

G. Douglas Fir.

It had better be called Pseudoabies than Pseudotsuga. Cones are ripe in October; bracts are twice as long as scales; seeds fall immediately. Germinating percentage is 20 to 30 per cent.; seed received from dealers is apt to lie over. Thorough mulching or hothouse treatment (after Weise) increases the percentage and the rapidity of sprouting. Germination takes place after five to seven weeks. The five to seven cotyledons are pointed and show two white stripes and a raised midrib above.

Two varieties of Douglas Fir:

a. Pacific Coast Douglas Fir, growing rapidly, foliage bluish, large cones, two top shoots during summer, the second one usually from a side bud.

b. Rocky Mountain Douglas Fir, known as varietas glauca, owing to its grayish foliage, of very slow growth, greater hardiness, smaller cones, developing only one shoot annually. Price of seed: $3.75 per pound.

H. Lawson's Cypress.

Cones blue brown, globular, only six scales, small, three seeds under scale, seeds two winged. Wing one-twenty-fifth inch wide. Seeds mature in September and October, falling at once. 150,000 grains per pound. Sprouting with two cotyledons only, one-fifth to one-third inch long. Young seedlings stand shade. In the sapling stage, fungi seem to play havoc in the plantations, a fact which may explain the small range of the species. Seed 60c per pound.

I. Western Red Cedar (Thuja plicata).

Scales of cones oval and upright, covering pairs of seed. Seeds two-winged; wings one-quarter inch long, elliptical, drawn in at top. One pound contains 300,000 grains. Two cotyledons only. Seed cost $2.25 per pound. Seedlings stand heavy shade.

Paragraph XVIII. Actual planting of seedlings: Introductory remarks.

A. The forester uses seedlings one to ten years old or, better still, one to five years old. The planting expenses increase at a cubical ratio with the increasing weight of the plants.

B. Seedlings are planted either with or without "balls" of dirt. They are taken from the nursery or from the woods. Yellow Pines over three years must be planted as "ball plants." Ball planting is always safer, as it involves a small loss of root fibre. Under any circumstances, it is wise to leave as much dirt as possible attached to the roots, preventing the roots from drying and allowing them to quickly re-establish their sucking contact with the pores of the soil.

C. The small stemlet of young seedlings might be cut off before planting (stump plants). Advantages of planting stumps:

I. In case of Locust, etc., lack of thorns.

II. In case of tap rooters (Walnut, Hickory, Oaks where loss of root fibre is great), rapid re-establishment of the equilibrium previously existing between water-sucking power and evaporation.

III. Certainty of planting the seedlings neither deeper nor higher than they were in the nursery.

Conifers cannot be stump planted.

If stump plants of Ash or Maple are to be used, stumps one and one-half to two inches high should be left. In the case of Oak, the stemlet should be cut off just above the point of differentiation. Stumping seems practicable in the case of Chestnut as well, and is often applied to Catalpa, Locust and Honey-Locust. Stumping is objectionable on account of the rabbits eating the new shoots, or where weeds are rank.

D. Bunch planting is often practiced where very small seedlings, cheaply raised and not transplanted in the nursery, are thereafter exposed in the woods to atmospheric hardships or to damage by animals. From two to thirty such seedlings form a bunch planted into one hole. Bunch planting is applied to German Spruce and Beech, although losing favor with the foresters abroad.

E. Plants may be planted irregularly or else in triangles, squares, rectangles. The advantage of an exact regular arrangement, which may be obtained with the help of long planting strings, bearing blue and red marks, are:

I. Saving of time and expense. Each workman is kept busy by the work of his neighbor, and none can fall behind. Supervision by rangers is facilitated.

II. The number of plants needed is easily found and the probable expense is more accurately estimated.

III. Small seedlings can be found easily in high weeds or grass.

IV. A plantation may be opened to pasture at an earlier date.

V. A mixture of species, and, later, underplanting are more readily obtained.

VI. The cleaning, thinning and pruning of the plantation is facilitated.

VII. Possibility of cultivation between the rows in prairies and on abandoned fields.

The triangular form gives the largest number of plants per acre, distributes the growing space equally, and is therefore said to raise cleaner stems. The arrangement in squares allows for a given planting distance 15% less plants per acre than the triangular system.

The rectangular system, though scientifically objectionable, practically prevails over the others. The plantlets standing close within a row assist one another from early times on. Planting between the rows and the cultivation of slopes are facilitated within rectangles. It is said, however, that the saplings form large side branches and retain the same for a longer period of years. **Rectangular** plantations are known to suffer less from snowbreak.

F. Usually it is best to make the holes for the plants before planting—unless, on clay soil, the holes are apt to fill with water. The making of holes takes more time, in many a case, than the planting itself. It should not be done during the few spring days favorable to tree planting.

G. The rangers should make all needful preparations for planting several days or weeks before planting, securing the seedlings, "heeling them in" close to the plantation and getting the implements and tools in proper condition.

Planting distance.	No. of plants per acre in squares.	No. of plants per acre in triangles.
1 foot	43,560	50,650
2 foot	10,900	12,674
3 foot	4,850	5,640
4 foot	2,725	3,168
5 foot	1,750	2,034
6 foot	1,210	1,407

Paragraph XIX. Criteria of good seedlings.

A. The root system:

The root system should be as compact as possible and as rich in fine hair fibres as possible, qualities which are only obtained in a well-fertilized nursery. It must be remembered that the small hair fibres are the feeders of seedlings, and that the stronger roots act merely as bones or as the skeleton giving the plant a firm anchorage in the soil.

A short exposure to sunlight and to dry winds kills the root hairs. Roots cannot live in air any better than fish, though requiring oxygen like fish. Toumey claims that "many successful planters never set evergreens until the root tips show signs of growth." This experience is entirely at discord with the universal European experience. Conifers are very sensitive against loss of root fibres. Fresh tips, evidently, are most apt to be injured in handling or by drought.

The pruning of the root system is a necessary evil in the case of very long tap roots. Conifers do not allow of it. Badly damaged roots may be clipped with a sharp knife just above the damaged point.

B. The shaftlet: Crooks are not injurious, the plant healing them quickly. Slender plants are not desirable, partly because they sway badly in the wind, thus getting loose in the soil; partly because slender shafts are due to excessively close position in the nurseries. In the case of broad-leaved seedlings one or two years old the shaft of spindling specimens may be cut off without lasting injury (not in conifers).

C. The buds: The buds must have a healthy color, a large size and a goodly number. Small buds prove the plant to be weak; so that it has a poor chance to withstand the hardships of transplanting. In conifers, the condition of the buds is especially telling. Poor and few buds in hardwoods render it advisable to lop the stemlets.

Paragraph XX. Age, size and number of seedlings used.

A. Young plants are more easily transplanted than old plants, the loss of root system being smaller. Large saplings (10 ft. high to 4 inches in diameter) are transplanted only at great expense and great risk. They must be transplanted with big balls of dirt attached.

B. The number of plants used per acre in Europe varies between 1,000 and 40,000 specimens per acre in case of Pines, Spruces and Beeches. The advantage of a large number of small plants is:

I. Better chance for nature to select the fittest.

II. Less reinforcing required.

III. Even unexperienced planters can be used.

IV. Plant material is very cheap.

V. Larger returns from first thinning and clearer boles.

On the other hand, the advantage of planting stronger seedlings, especially transplants three to six years old, lies in the following points:

VI. On poor soil, strong plants have a better chance.

VII. Older plants have already overcome the "measles" of childhood—fungi, insect diseases—to a large extent.

VIII. Such plantations suffer less from snowbreak.

IX. The rotation is shortened by a number of years. In a White Pine plantation made with seedlings seven years old, instead of seedlings two years old, the rotation is reduced from fifty to forty five years; and the original cost of planting may be 27% higher, figuring at 5% interest; 22% higher, figuring at 4% interest; 13% higher, figuring at 3% interest.

C. Generally speaking, Oak, Hickory and Walnut should be planted one year old on account of the large size of the tap roots.

Spruce, Fir and Hemlock should be planted three to five years old, after previous transplanting in the nursery. Ash should be planted six years old when used in half swamps having luxurious growth of weeds. Yellow Pine must always be planted one or two years old, unless ball planting is resorted to.

After Toumey: For the prairies, yearlings are best in case of Cottonwoods, Box Elder, Soft Maple (Soft Maple sprouts in June and is very small in fall), Russian Mulberry, Catalpa, Walnut, Black Cherry, Locust and Honey-Locust. At Biltmore, Black Cherry transplants three years old do very well. Locusts two years old are clipped back. Maple and Ash are transplanted and used three to four years old; Yellow Pines are used one or two years old; White Pines two, three or four years old; Catalpa one year old, etc.

Paragraph XXI. Lifting seedlings from nursery beds.

It is not advisable to plow the seedlings out of the ground or to tear them out with tongs. In the case of species having small reproductive power (Conifers, Beech, Birch) additional care is needed. The spade should be used; and the plant should be lifted together with large clumps of dirt which, thrown on the ground, collapse and allow of safe extrication of the plants contained in the clumps.

It is wise, carriage charges permitting, to allow some dirt to stick to the roots. On more binding soil the hollow cylinder spade might be used for lifting small plants. Plants should be well covered with burlaps, wet moss, dirt, etc., at once after digging. Plants left for a number of days between the plantation and the nursery should be heeled in thoroughly, shinglelike, one row covering the other, in a shady place.

Paragraph XXII. Transportation of seedlings.

The roots are thoroughly protected. A voyage from Europe to Biltmore, though it may take six weeks time, will not injure the plants. Plants are loosely put together in bunches of one hundred to two hundred pieces, are placed in baskets or open crates, the roots in the center, the tips at the circumference. Layers of plants alternate with layers of damp moss. Seedlings packed tightly, especially in boxes, are apt to mould.

Plants merely taken to a nearby plantation on wagons should be well covered with branches, moss or sacks, and should be sprinkled during transportation. Ball plants do not need packing unless balls are very loose. when burlaps are necessary. One hundred Yellow Pine ball plants, after Rankin, with balls ten inches square, make up a two-horse load. Fifty thousand seedlings without balls and well watered, or eighty thousand seedlings slightly dampened, usually make a wagon load.

Paragraph XXIII. Common methods of planting seedlings in the open.

A. Planting in furrows.

The furrows should be made deeply with a subsoil plow. The plants are distributed, at proper distance, in the furrows. Then another furrow is at once given with a turning plow, throwing the needful dirt over the plants, which are thereafter adjusted and pressed into proper site, by hand.

This is a quick method of planting, but is practical only on prairies or on abandoned fields. It involves the danger of reckless spreading of roots and of loose imbedding of the plant in loose soil. The plants are also apt to be placed too deep and to be shaken badly by wind. The method, however, yields good results in case of

I. Stump planting (Oak, Locust, Catalpa).

II. Planting many one-year-old seedlings (so that a large percentage might be lost without great injury).

III. Plants not sensitive to deep planting (not for White Pine and Spruce). Plants placed too deep form a second root system close to the surface and develop a bushy bole, useless in forestry, pleasing in a garden.

At Biltmore, the furrow method was used by Pinchot at the Shiloh Crossing plantation. A modification of the furrow method was used at the Rice farm in 1903, where deep furrows were drawn, the plants inserted by hand, covered by hand and adjusted by hand. A planting machine (Dr. Fernow's), resembling a tobacco planting machine, is not used.

B. Planting in holes. The holes are either holes dug with the spade or clefts wedged into the soil. Most planters mulch the roots in loamy water so as to increase their weight and so as to reduce their spread before insertion into the hole. The root fibres suffer from this mulching, however, being braided unnaturally. The root tips should not be bent upward. The depth and width of the hole should correspond with the actual size of the root. Several plants might be placed in the same hole to save expense. Theoretically it is best to place each plant in the center of its hole. At Biltmore, however, planting in the lower edge of the hole is preferred because:

I. No root is hemispherically developed.

II. Planting at the edge is the best preventative against deep planting, the planter holding the plant with the left hand at the point of differentiation against the edge of the hole, when drawing with the right hand the dirt required to fill the hole.

III. Such plants are firmly imbedded and are less shaken by the wind. On forest soil it is wise to place the top dirt dug from the hole around the root tips, and the bottom dirt of the hole close to the surface. The workmen should be shown daily by the forester how to plant. It is of the utmost importance to pulverize and loosen the dirt first, and to then press and beat it tightly with fist, heel or mallet around the roots. Some planters give a trifle of forest humus into the hole; others carry fertile garden dirt in baskets to the plantations. The placing of stones on the hole (as refrigerators) is recommended. One man's work at hole digging per day is 300 to 3,000 according to root-size and conditions of soil.

C. The seedling must stand, after planting:

I. Firmly, the dirt being tightly packed around its roots, so that it cannot be shaken and so that the roots may establish their sucking contacts.

II. Naturally, the roots having the same manner of spreading and ramifying which they had in the nursery.

III. Erect and just as deep as it stood in the nursery (exception: barren sand).

Paragraph XXIV. Special methods and tools used for planting seedlings in the open.

A. Biermans spiral spade, costing $2.00, is pointed parabolically, the blade being 7½ inches long and 5 inches wide. When used boringly, this spade forms a parabolic hole and loosens the soil. With the left hand the seedling is pressed against the side of the hole, while the right hand places some sod ashes (See Par. XXIX, D. VI.) immediately over the fine root fibres. Then the best part of the soil is used to fill the near half of the hole, and the poorest for filling the far half. The instrument is adapted to hardened soil. On wet and binding soil, the dirt clogs in the curves of the spade. Capacity per hand in Germany 320 plants per day.

B. The Planting Dagger is used for Yellow Pine seedlings one or two years old, to be planted on sandy soil. The dagger is three inches longer than the longest root. It is made of wood, iron shod at the point. It makes a narrow, funnel-shaped hole, which is closed by pressure from another hole made a few inches from the first. On loose, sandy soil it is wise to plant Yellow Pine seedlings deeply—up to first needles—since Yellow Pine is not affected, in that soil, by deep planting. Daggering is the cheapest possible method for planting Long Leaf Pine, Jack Pine, Lodgepole Pine, etc. Capacity 800 to 900 per day and hand.

C. The Buttlar Iron, once much used for thrusting holes into the soil, is now in disfavor since it causes the seedlings to be inserted into holes having walls as impenetrable as those of a flowerpot. Only plants one or two years old can be thus planted ("cleft planted").

D. The Wartenberg Iron consists of a sword 18 inches long, attached to a heavy handle. Price $2.25. Similar irons were made at Biltmore out of three-inch wagon tire, at a small cost. A deep cleft is made by the iron in which tap-rooted seedlings are readily inserted. On binding soil, however, or in a broomsedge field, the use of this iron cannot be recommended.

E. The planting hammer is used to make small holes for small roots. The iron part of the hammer is about five inches long. The planting hatchet, a similar make, may be used to advantage for planting one-year-old plants. The holes are closed by beating the dirt round the holes with the back of the hammer or with the hatchet.

F. Von Alemann constructed a very heavy square spade which is pushed and drawn in a particular way, like the lever of a handcar on the railroads, so as to make the lower part of the hole wider than the middle part, the cross-section of the whole forming an X. If Oaks are planted, an extra hole is made at the bottom of that made with the spade, by means of a long dagger in which the tap root of the oak is to be imbedded. The hole is closed by pressure from the sides. It seems doubtful whether the soil will close entirely over the roots unless it be sandy. One man can plant 580 Oaks two years old or 1,270 Yellow Pines two years old with this instrument on plowed ground.

G. The Planting Beak, constructed by Barth, makes and empties a triangular hole, taking out the dirt filling the hole. Plants one or two years old are placed along the vertical side of the hole. Then the dirt kept in the beak is filled in. The instrument is 3½ feet long and weighs 15 pounds. It is said to be superior to all cleft planting tools, whilst it works just as cheaply on loose soil.

H. Planting under sod cover. (Von Alemann). Two sods are turned over, like the covers of books, and laid back, upside down, without loosening the "hinge" of the sods. The soil in the hole is deeply worked with a spade. In the middle of the hole the plant is placed, with the roots spread as much as possible within the entire hole. Then the two sods are turned back into their original position, so that the seedling stands between them. This is a good method on ground where frost is to be dreaded, and is used for Ash, Alder and Water Birch one to three years old.

I. Mound Planting (Manteuffel). Small mounds are made consisting of rich nursery soil to be carried in baskets to the plantations. The plant is placed into the mound, its roots touching the vegetable mould underneath. The mound is covered with sods to prevent erosion. The method works well on very dry and hard ground. About 100 plants are planted per day and per man after this method. Its advantages are:

I. The vegatable cover of the soil, by its disintegration, furnishes food for the rootlets.

II. The quality of the soil surrounding the roots is very good.

III. The soil in the mounds is kept moist with condensed atmospheric vapor, owing to its greater porosity.

IV. The planter is not likely to plant the seedling too deep.

The method is also applied on very wet soil. The mounds may be replaced by ridges. Experiments have shown that planting in mounds does better in years of drought than planting in holes.

Modifications of the Manteuffel method are in common use. Ordinary soil dug out at the planting site may be used to make the mound; or, where there are heavy sods, a sod is turned upside down and left to rot for a year. The mound thus made is rich in plant food resulting from the disintegration of root fibres and vegetable matter.

Disadvantages of mound planting are:

a. The mounds are easily washed away on slopes unless under cover of mother trees.

b. The best soil is washed out if the mound is not covered with sods, stones or brush.

c. Insects and mice find hiding and breeding places in the sod-covered mounds.

d. Mound planting is very expensive.

J. Ballplanting, with Charles Heyer's hollow cylinder spade.

The cylinder spade can be used to best advantage on binding soil. It lifts the plant (seedlings, notably conifers one or two years old) from the nursery without loss of roots and prepares for it a hole on the ground to be planted having the exact form of the ball of dirt adhering to the roots.

The method is particularly safe and seems particularly adapted for prairie planting since it protects the seedling before, during and after the act of planting; since it prevents the seedling from loosing its foothold in the soil under the influence of high winds; since it allows of planting at almost any season of the year.

On stony soil, the cylinder spade cannot be used. Edward Heyer's "cone spade" facilitates the transfer of larger seedlings with heavier balls of dirt from the nursery or from the woods to new plantations.

Paragraph XXV. Season for planting seedlings.

Factors influencing the season are:

Local climate.

Labor available.

Time available.

Species planted.

Theoretically seedlings should be planted during the period of inactivity of roots and buds, or in mid-winter. This theoretical demand, however, in a Northern climate, cannot be carried out, the ground being frozen at that time. Hence the choice only remains between planting in late fall and planting in early spring. After Engler, roots show two periods of active growth, viz.: a spring-and-summer period influenced by soil moisture, and a fall period influenced by soil heat. The growth of the roots during August and September, between the two periods mentioned, is very weak.

In spring, the growth of the roots starts in March and April and shows the highest activity in May, June and July.

A. Spring Planting.

The seedlings are planted before the opening of the buds. The moisture left in the soil by the melting snow is very favorable to their growth. Objections to spring planting are:

I. Scarcity of labor, unless forest planting begins at a time at which fields are too wet to be worked.

II. Larch, Maple, Cherry and Birch sprout so early in spring that it is impossible to adopt spring planting in their case.

III. Moist ground, hummocks and swamps are not accessible in spring.

IV. The soil is not packed as tightly around the roots on the arrival of spring as is the case in fall planting.

B. Fall Planting.

Fall planting is preferred on wet areas and in the case of early sprouting species. The disadvantages of fall planting otherwise outweigh the benefits combined therewith.

I. Seedlings planted in fall are apt to be heaved up by the winter's freeze.

II. The severe winds of the winter loosen the foothold of conifers planted in fall.

III. Fall-planted seedlings are more subject to late frost, opening their buds some ten days earlier than spring-planted seedlings.

IV. On weedy soil, fall-planting is handicapped by the presence of a rank growth of weeds which has rotted down at the arrival of spring.

In the Southern states, even at Biltmore, planting in January and February is very feasible, perhaps advisable in average years.

Ball plants can be planted at any season of the year.

In countries of periodical rainfall (California, India and Porto Rico) it is best to plant just before the beginning of the rainy season.

In swamps, summer planting or early fall planting is a necessity.

Paragraph XXVI. Cultivation of plantations.

A. Practice: The European forester never cultivates any plantations for the reason that his plantations are made immediately after lumbering, when the rootwork and the stumps on the ground render cultivation difficult. Under the incident conditions of soil (humus; porosity), cultivation is usually not required for the success of a plantation. Irregular plantations cannot be cultivated.

The forester afforesting sand dunes obviously objects to cultivation.

The forester afforesting swamps finds cultivation impracticable.

B. Advisability: Cultivation is advisable:

Where there is neither humus nor rootwork in the ground;

Where the soil, like prairie soil, is compact and hard, lacking in aeration, porosity, capilary power, hygroscopicity;

Where competing herbaceous weeds threaten to smother small seedlings;

Where mice or soil breeding insects prevail, which are disturbed, exposed or killed by continuous cultivation.

C. Frequency.

The forester may cultivate up to three times per annum, during one, two or more years—sometimes till the leaf canopy overhead secures for the soil a solid layer of humus by dense shading.

D. Tools.

A bull-tongue plow is used, on rough ground, for plant rows placed less than three feet apart.

Cultivators are used, as in agriculture, where the soil is loose, and where the rows are far enough apart and the ground is free from stumps or roots or bolders.

Hoes are used in exceptional cases only, where labor is cheap and where the soil does not allow of using teams and machinery.

Mules and horses are muzzled to protect broad-leaved seedlings from being browsed.

Paragraph XXVII. Prairie planting in particular.

A. The prairie exhibits as marked climatic differences as the State of Georgia compared to the District of Labrador.

"General prescriptions for prairie planting" are impossible, owing to these climatic diversities.

B. The species used must be adapted to the quality of the soil, the intensity of summer heat, the duration of the summer, the soil moisture, the air moisture. Native trees should be given the preference in case of doubt.

C. Prairie plantations are meant either for production of timber (ties, posts, etc.), or for shelter to stock, house, orchard and field.

D. Species recommended for prairie planting are:

I. For Canada:

White Spruce, Cottonwood, Balm of Gilead, Box-elder, Green Ash, Russian Poplar; further Yellow Pines.

II. For Minnesota and Dakota:

Cottonwoods, Soft Maples, Willows, Ashes, Box-elder, Tamarack in swamps, Bur Oak along rivers.

III. For Nebraska and Iowa:

The same species and Red Cedar, Russian Mulberry.

IV. For Kansas, Arkansas, Oklahoma and Missouri:

Osage Orange, Black Locust, Hardy Catalpa, Post Oak and White Oak.

E. Naturally we should expect Xerophytic species, like Yellow Pines, to do best in the prairies, and the old stumps found buried in the ground bear testimony to their possibilities. Being evergreen the Pines protect the farmers best from blizzards. Still, just Pines are most apt to meet with distress previous and after the act of planting. Ball planting should be tried. The European Pinus montana resists wind particularly well.

F. Preparation of soil: It is best to prepare the soil thoroughly by several years' field crops. Deep plowing is required (Toumey) in the fall previous to planting and in the spring of planting.

G. Preparation of plants: The seedlings arriving at the farm should be removed from the package; heeled in under shade, protected from winds and sprinkled if frost is not to be feared. Toumey wishes to puddle plants before heeling, and desires to plant the conifers invariably after the broad-leaved kinds.

H. Planting: The planter must patiently wait for proper weather. Thorough protection of the roots during every moment of the act of planting is essential. Each individual must be planted by itself—no dozen methods! The plants should be set closely within the rows; the soil must be packed tightly round the roots. Reversed sods or stones may be used to ballast the roots and to prevent the wind from shaking them loose.

I. Cultivation: Cultivation is necessary up to the time when the trees cover the ground fully, littering it with humus. Where barefrost is dreaded, cultivation should end in late summer.

Paragraph XXVIII. Methods of obtaining plants for planting.

A. Frequently, seedlings are obtained from the woods nearby, a method which seems to recommend itself as cheap and natural. It is a fact, however, that the roots and the buds of wild seedlings are badly adapted for the purpose of planting. The former are far-spreading; the buds are weak and few. In addition it is risky to take plants from the shelter of mother trees suddenly onto open ground. The use of wild seedlings over two years old is particularly unsuccessful. The failure of the timber culture act to prove efficient is largely due to the use of wild plants in prairie plantations.

At Biltmore, seedlings of Yellow Poplar, Yellow Pine, Ash and Maple are often picked up with a spade and taken to the nurseries with good results. Such seedlings are taken at a very young age, without loss of dirt, to nurseries placed under lath screens. They are never removed directly to open plantations, with the exception of ballplants of Yellow Pine.

B. Purchase of plants from commercial nurseries:

During the last 15 years, a number of financially strong commercial nurseries have arisen abroad which, buying seed cheaply, located on suitable ground at good shipping points, enjoying many years' close acquaintance with the needs of Sylviculture, have supplied the various German administrations with cheap plants of a superior grade. The Biltmore Estate has often obtained plants raised by Heins Sons, Halstenbeek, near Hamburg, notably White Pines, which have been very successful in spite of a six weeks voyage. On the other hand, American nurseries usually prepare plants only for ornamental purposes and not with a view of fostering the development of the tree bole.

Since the rangers and the helpers in forest planting should know the sylvicultural needs of the seedlings, it is surely wise to offer them object lessons at home through self-administered nurseries.

C. Nurseries proper, in charge of the forester.

Where mice are much feared the nurseries should be surrounded by a deep; straight walled ditch. Fences are made of wire, lath, rails, etc., differing in material, strength, height and fineness of mesh according to the enemies locally dreaded.

Proper nurseries yield the largest percentage of seedlings out of a given quantity of seeds. The seedlings raised therein have a better, more compact and more fibrous root system than wild plants. Expensive and exacting species should always be raised in "forest gardens."

There may be distinguished:

Nurseries under tree cover.

Shifting nurseries.

Permanent nurseries.

I. Nurseries under tree cover form the exception, being required only for the production of seedlings of tender species; notably of Hemlock, Hard Maple, Beech. The nursery is formed by a polewood heavily thinned and dug over with the spade. Here Beechnuts are planted broadcast or in furrows and the seedlings removed when two years old, without transplanting. Hard Maple and Hemlock should be raised as in open nurseries.

It is a noteworthy fact that broad-leaved kinds often thrive best under conifers (Oak and Beech under Pine) and conifers best under broad-leafed kinds (Spruce best under Beech, Maple, Birch). Only theoretical explanations can be given for this truism, the best explanation being the difference of enemies attacking such species.

Objections to nurseries under tree cover:

a. Soil preparation is costly and insufficient.

b. Plants raised cannot be planted in the open without loss.

c. Nurseries under tree cover suffer badly from mice and squirrels and obtain insufficient rainfall. On the other hand, weeds and grasses are kept down by the shelter overhead.

Nurseries under tree cover form the exception, not the rule.

II. Shifting versus stationary nurseries.

The advantages of stationary forest nurseries over shifting forest nurseries are:

a. Reduced cost of tilling.

b. Reduced cost of fencing.

c. Reduced cost of supervision.

On the other hand, stationary nurseries suffer from:

1. Excess of weeds.

2. Higher cost of transportation of seeds and seedlings.

3. Large needs of artificial fertilizing.

4. Danger from mice, insects and fungi for which such nurseries act as incubators.

For raising ball plants, the shifting nursery is undoubtedly best; otherwise the selection between shifting and permanent nurseries depends on local conditions; such as the price of manure and of fencing; charges for transportation, etc. Seed plantations made on open ground are often used as shifting nurseries—especially so in the case of Yellow Pines.

Paragraph XXIX. Permanent nurseries in particular.

A. The size of "forest gardens" (the German name for stationary nurseries) depends upon the quantity, the age and the size of the seedlings annually needed. Further, on the presence or absence of transplanting beds, fallow beds and paths between the beds. Regular forest management has forest gardens fitted with:

I. Transplanting beds, their total size being equal to transplanting space by number of plants yearly needed by number of years which the transplants are left in such beds.

II. Seed-beds, their total size being equal to one-fourth of size of transplanting beds for one age class by number of years which the seedlings are allowed to stand untransplanted.

III. Foot paths and roads equaling 30% of I and II.

IV. Fallow beds equaling 100% of I, II, and III, if seedlings and transplants are left for one year only in their beds; 50% of I, II and III, if left for two years; and 33%, if left for three years.

B. Form of beds. Beds are usually four to six feet wide, separated by paths one or two feet wide, the beds preferably elevated over the paths by from three to twelve inches, so as to check the migration of insects, mice and moles; and so as to allow of better aeration of the soil. Sometimes the beds are kept in board frames, an expensive though useful arrangement.

C. The following factors must be considered in selecting the site of a nursery:

I. Soil: A sandy loam or marl is best for seedlings. The correct degree of looseness is secured by mixing sawdust, spent tan, humus, ashes and weeds with the mineral soil. The soil should have no stones, in order to allow of proper seed planting and in order to facilitate the digging of the plants.

II. Exposure: The best exposure is a gentle northwest slope. The bottom of a valley is too frosty in spring. Southwest and southeast slopes are subject to rapid atmospheric changes. Eastern aspects invite damage by frost.

III. Proximity to water and possibility of irrigation.

IV. Accessibility and distance from ranger's house.

D. Fertilizing: Stationary forest gardens require continuous fertilizing. Crops of seedlings exhaust the soil like grain.

The following table exhibits, in pounds per acre, the amounts of fertilizing matter annually consumed by Pine seedlings, Pine poles and crops of rye.

Fertilizing matter.	Yellow pine one year old.	Yellow pine eighty years old.	Crop of rye.
Phosphoric acid	9.8 lbs.	1.7 lbs.	16.7 lbs.
Potash	20.7 lbs.	2.8 lbs.	24.2 lbs.
Calcium	17.2 lbs.	10.1 lbs.	9.7 lbs.
Magnesia	3.0 lbs.	2.0 lbs.	4.2 lbs.
Sulphuric acid	0.0 lbs.	0.3 lbs.	1.1 lbs.

The following fertilizers are used in forest gardens:

I. Animal manure, which is considered best. Cattle manure is preferred to horse manure; on clay soil, however, horse manure is better. Heavy weeds come up from stable manure which has not had time to fully decompose.

II. Commercial fertilizers: Experiments conducted with superphosphate, bone meal and so on have failed to yield conclusive results. The best kalium fertilizer seems to be kainit (kalium chloride); the best nitrogen fertilizer is saltpeter.

After Von Schroeder, the following quantities of phosphates, potash and nitrates are needed to raise 4,000,000 plants on an acre of nursery:

520 lbs. kainit.

60 lbs. superphosphate.

320 lbs. whale guano.

III. Humus, the natural forest manure, is the cheapest fertilizer obtainable in the woods. Humus of Pines mixed with that of broad-leaved species is best. Humus just one year old is said to be richest in bacilli favorable to tree growth, and to be devoid of filiform fungi disastrous to plants.

The weeds removed from nurseries furnish, through their decomposition, a valuable humus.

A mixture of humus with street sweepings, kitchen refuse, loam, burnt lime, etc., is often placed in huge heaps near the nurseries. The heaps are kept in a rotation so that the heap made in 1903 is used only in 1906. The heaps are stirred up repeatedly so as to be acted upon by the air.

IV. Vegetable matter other than humus. Such fertilizer may be obtained by raising, on the fallow beds, during the fallow year, cowpeas, clover, lupine (the latter on sandy soil) and other leguminous plants, all to be plowed under in fall.

Leguminous plants increase the nitrogen in the soil.

V. Wood ashes: Excessive use of wood ashes is disastrous to sprouting plants, especially on sandy soil. Besides kalium, wood ashes contain from 5% to 20% of phosphoric salts. Wood ashes should be used, however, moderately in Yellow Pine nurseries.

VI. Sod ashes are recommended where other fertilizers are too costly. Sods of grass, of weeds or of huckleberries are dried, the majority of the dirt removed and used to build a chimney and a kiln resembling a charcoal kiln, wherein layers of sod alternate with layers of brushwood, waste thinnings, etc. The kiln is covered with sods and wet dirt. Kilns burn, according to size, for from two days to two weeks. The sod ashes contain all mineral fertilizers needed; have great hygroscopicity and are free from insects, fungi and other bearers of plant diseases.

Sod ashes should be exposed to the atmosphere for a year before use, and should then be well mixed with the top layer of nursery dirt.

Paragraph XXX. Seed planting in seed beds.

Seedbeds: Prescription for preparation: Plough and cross-plough to a depth of one foot; mix manure well with soil; heap the dirt taken from the paths on top of the beds; remove stones.

Seeds are planted either broadcast or in drills to a depth generally equaling their longest dimensions.

A. Broadcast planting is always used in commercial nurseries while the sylviculturists use it only for seeds of small germinating percentage (Birch, Elm, Beech, Alder and Yellow Poplar) or in case of very light grained species which do not allow of any covering.

Broadcast planting is permissible if seedlings are kept in the bed one year only. Economy in size of nursery and less weeding are the advantages of broadcast planting.

With the help of a roller or, better still, of a heavy plank, the surface of the seed bed is pressed down until an even surface is obtained. Then the seeds are planted, dirt or fertilizer or sod ashes sifted on top, and the surface of the bed again pressed down as before. To prevent the formation of a crust, a cover of moss or leaves is often given, to be removed before the time at which the cotyledons are expected to appear. Better than moss or leaves are coverings consisting of Pine branches (exception: on Pine seeds).

B. Planting in rills. The rills are from one-fourth to three inches wide; made with a "rill board," a plank well seasoned to which mouldings are nailed. These mouldings may either be square or triangular in their cross sections.

The rills are from five to ten inches apart. Double rills are preferred, lately, in Germany. In order to economize in the use of fertilizer and in order to obtain a compact root system, trenches are sometimes made and filled with particularly fertile soil, at a distance apart equaling that of the rills. These trenches are made with a special "trench hoe," triangular in shape. The seed is put in the rill with the hand, with the help of a reduplicated playing card, a bottle of seed or, better, a stick 2″x4″ groved on one side and as long as the width of the bed, or, best of all, a hinged gutter into which the seeds are filled by "thimblefuls" or "spoonfuls," evenly distributed in the base of the gutter. The gutter is placed over the rill and opened by pressing the two sides together, when the seeds drop through the "slot." To insure even distribution of the seed in the gutter, small niches may be provided at short, equal intervals at the base of the gutter, the aggregate size of the cavities corresponding with the quantity of seeds to be planted in each rill.

Advantages of rill planting:

I. Economy in seed.

II. Stronger plants of more compact form grown at proper intervals apart.

III. Economy in manure.

IV. Seeds put at proper depth.

V. The foot of plantlet can be easily covered with moss or leaves.

VI. Weeding is made easy.

Unless very experienced help can be had, rill-planting is certainly preferable. Undoubtedly, however, insects, mice and moles following the rills do greater damage than in broadcast planting.

The quantity of seed per square foot of seed bed depends on the number of seeds in a pound; the germinating percentage; the quality of soil; the number of years which the seedling is meant to stay in the beds; rapidity of growth. Oak 2% of a quart; Beech and Chestnut, 4% of a quart; Locust, Ash, Maple, Elm, Birch, 30 grains; Alders, 45 grains; Fir, 150 grains; Yellow Pine, 15 grains; Spruce, 20 grains; Tamarack, 30 grains; avoirdupois—all per square foot.

The figures given are illustrations, not prescriptions.

Heavy seeds (nuts) are usually dibbled in, with a "dibbling board."

Paragraph XXXI. Transplanting in transplanting beds.

Transplanting is expensive. It must be done at a time when forestal labor is anyhow fully occupied. Transplanting is, therefore, resorted to only

A. In case of very expensive seeds or seedlings.

B. In case of very slow growing seedlings.

C. In case of plants exposed in the open to severe dangers (drought, frost, game, mice, insects, weeds).

To avoid transplanting, the following alternatives are used:

I. The offspring of very cheap seeds (German Spruce) is "singled out," weaklings or individuals standing crowdedly being pulled out by hand, or being cut out by scissors.

II. "Root pruning" is adopted which inforces a compact root system by cutting off, with a sharp spade, far-spreading roots, or long tap roots.

The transplanting distance is, at least, three by six inches and is governed by rapidity of growth expected and by the number of years which the transplant is to be left in the transplanting bed.

Transplants are set in clefts in the transplanting bed made with the help of a transplanting dagger, or are placed into trenches made with a hoe or spade.

Planting boards may be used, along which the seedlings, whilst pressed into equidistant slight grooves, are held in proper position by a string tightly spanned.

Transplants are often left for one year only in the transplanting bed, although the act of transplanting weakens the plant temporarily, thus checking the first year's growth in the transplanting bed. Conifers should not be transplanted more than once. Hardwoods are rarely transplanted more than once, excepting the Ash, saplings of which are used for planting hummocks.

Paragraph XXXII. Protection of nurseries.

A. Protection of nursery plants against drought: Lath covers, cloth covers, branches, cornstalks, top covering of slabs, laths, etc.;

cultivating rows of plants; watering which must be continued if once begun.

B. Protection of nursery plants against frost: Same measures as in "A" inclusive of watering; smoking fires; pressing seedlings lifted by frost back into the bed; no weeding from September on.

C. Protection against excessive rain (which washes the plants out, or splashes them with mud-pants, or incrusts the surface): Top dressing of leaves, moss or Pine branches; "combing" mud-pants off the seedlings; lath or brush covers.

Paragraph XXXIII. Nursing in nurseries.

A. Weeding: Weeding is facilitated in nurseries by a regular arrangement of the plants and by narrow beds. Tools are: knife, fork, hoe or special weeding wheels. Weeding should be stopped a month before frost comes in. The purpose of weeding is not only the removal of competitors; it is also aeration of the soil.

Weeding can be dispensed with in dense, broadcast seed beds; in thinly stocked beds planted broadcast it is most necessary and most difficult.

B. Cultivation: Cultivation in the transplanting beds of commercial nurseries (Beadle at Biltmore) is done by cultivators drawn by a horse. Cultivation in forest nurseries proper purports to break the crust forming under the influence of heavy rain fall. Usually the act of weeding cultivates the soil as well. Cultivation is most easily effected by drawing some strong nails driven into a stick along each rill. This cultivation, at the same time, disturbs and scares away mice, voles and insects.

C. Carpeting the intervals between rills or rows:

Reversed moss, spent tan, sawdust, straw, hay, twigs (always of another species), poles (never fresh cut pine poles, which are incubators to snout beetles) are often laid between the rills or rows so as to preserve moisture, to prevent mud-pants from forming on the stemlets and to check weeds. These carpets, however, harbor mice and insects. Large leaves in the carpet threaten to smother young seedlings if blown upon them.

D. Trimming. The top shoot when killed by early frost or drought might be cut off. In no other case must it be touched. The side branches of broad-leafed species and of winterbald conifers might be clipped before or after planting and transplanting so as to reestablish the previous equilibrium existing between water sucking power of the roots now checked by transplanting and water evaporation from the crownlets left unchecked by planting. Species having a heavy central pith column should not be trimmed too close to the stemlet (Ash, Catalpa, Maple). Ash and Catalpa are apt to form forks which may be prevented by timely trimming.

Large broad-leaved plants planted in furrows often die, when shaken loose by winds. They may be saved if cut to the ground previous to June 15th.

Paragraph XXXIV. Special nursery methods proclaimed by renowned sylviculturists.

A. Biermans' method.

Peel the soil cover of an area four times the size of the seed bed and burn the sods thus gotten into sod ashes. Leave them over winter. In spring, mix one-half of the sod ashes with the stirred up top dirt of the intended seed bed. Spread the other one-half pure on top of the bed. Smooth the surface of the bed and press it with a board. Spread seeds broadcast as close together as possible, so that the soil is hardly visible between the grains. Cover seeds with sod ashes sifted on top, and press the cover down with a board. Transplant the young germs in June. Shorten the taproot of Oaks by cutting with a sharp knife. Oak nurseries should be underlaid with impenetrable soil. Yellow Pine and Larch should be used in the open when one year old; all other species two to three years old.

This method yields very well rooted seedlings. The use of sod ashes is, perhaps not an essential feature of the method; fertilizer or manure might be taken instead. The striking point is the transplanting of germs in June.

B. Von Buttlar method: Von Buttlar wants to raise long roots, not compact roots, for use in sandy soil. The nursery is worked to a depth of three feet, the bottom soil being brought to the surface. Larch, Fir and Elm seed are planted broadcast; all other species in rills. No transplanting. All species are used one or two years old.

C. Manteuffel method. The plants required by Manteuffel must have short, flat roots. Consequently, the best soil in the nursery should be the top soil, and the ground underneath should not be worked to any depth.

Remove by peeling the top layer of the soil, and beat the dirt out of the peeled sods onto the seed beds. Mix it with the dirt of the underground in fall. In spring, burn the sods and other vegetable matter at hand on the beds, mixing the wood ashes thus obtained with the top soil. Spruce shall not be transplanted and is to be used when two years old. Fir and all broad-leafed species must be transplanted.

Paragraph XXXV. Raising and planting hardwood seedlings on open ground.

Beech: Usual age of plants fit for use, two to five years. Transplants rarely used. Ball plants very successful. Bunch planting best, especially for underplanting. Do not cut stemlet to the ground and avoid pruning. Planting in open hardly successful. Beech best for underplanting. Almost light demander on poor soil. Beech is exacting (good soil and moisture). Instruments used are hoe, spiral spade, cleft irons.

Black Locust: Seeds should be planted two to two and one-half inches deep, an exception from the rule considering the small size of the seed. Drills eight inches apart. Germinating percentage of seeds very high. Seedlings are fit for planting when one year old. Usually, however, they are left in the seed bed for two years, and are then planted directly in the open. The planting of stumps and fall planting are strongly recommended. Plantations handicapped by twigboring moth (Ecdytolopha species) and by voles. Locust grown in the open is inferior to forest grown Locust.

Linden: Is usually planted in the open as a transplant three to four years old, or as a ball plant two to three years old. Spring planting. Good soil required. Pruning of branches a necessity. Plantations in Biltmore made in '98 on splendid soil, but without cover overhead, were slow to develop.

Oaks: The nursery treatment differs greatly according to local likes and forestry authorities relied upon. The treatment of the tap root is a continuous point of dispute. Manteuffel cuts the tap root one and one-half inches below ground (just as the voles did in Biltmore nurseries). Buttlar ties a knot into the root. Alemann forbids any crippling of the tap root, making an extra cleft in the planting hole to receive the tap root. Levret prevents the development of a tap root by placing the acorns on small macadam, covering them with one inch of dirt. The ground underneath the macadam must be hard.

Large areas of Oak planted in Northern Germany with the tap root cut off prove the success of Manteuffel's method. The hollow borer cannot be used. Trimming of branches is all right. Roots should be pruned, after Fürst, with a sharp spade at six inches below ground in the second spring. Spring planting is best. Some planters remove the first germ of the acorn ("offgerming") with a view to stopping the development of the tap root—very costly. Stump plants do very well, especially in the coppice woods. Usually seedlings one and two years old are planted. The use of saplings, transplanted repeatedly, is not advisable. Cleft planting of seedlings on broomsedge fields at Biltmore proves unsuccessful; the weeds choking and the rabbits eating the seedlings. Cleft planting in cutover woodlands, however, on fairly loose soil is a method to be strongly endorsed. In France the clefts are made inclined, not vertical; saplings 20 years old do not show any crooks due to the method. Planting of seedlings or of young transplants in spade holes, in furrows or in clefts made between the lid and the pit formed by reversed sods prove successful at Biltmore. Young plants are not subject to lifting by frost nor do they suffer from drought. The nursery should not be worked deeper than one foot while the success of the final plantation largely depends on looseness of ground at a greater depth. Generally Red Oak is more vigorous in early youth than White Oak. At Biltmore, Chestnut Oak is the best species for abandoned fields.

Chestnut: Soil well worked to a depth of sixteen inches, kalium a necessity, lime disastrous. Seedling planting (plants one or two years old) forms the rule; planting of stumps is also good.

Since Chestnut is very sensitive under changed conditions of growth, ball planting is probably the best method. Seeds are kept in the burrs over winter, or in layers alternating with layers of dry sand. Immediate fall planting, however, is best. Nuts are planted in drills two inches deep two inches apart, the drills six to twelve inches apart. At Biltmore planting of seedlings has met with continuous failure. Planting under cover or under an usher growth is probably advisable. Chestnut is exacting, needing atmospheric as well as soil moisture.

Tree Alder: It is usually planted as a transplant three to five years old. Yearlings are too small; seedlings two years old can be ball planted. Trimming allowed. Seeds planted broadcast on the beds, one-fourth inch of dirt on top. Sprinkling necessary. No protection against atmosphere needed. On swampy ground, fall planting of transplants is best.

Birch: Seeds very poor; those of Black Birch mature in summer. Seeds must be covered very slightly or, better perhaps, must be beaten with a shovel into the nursery soil after broadcasting. Formation of crust over seeds is best prevented by a cover of Pine branches. Under lath screens, stems are apt to damp off in June. Seedlings are planted either as two year olds, with or without balls, or as transplanted stumps three to five years old.

Birch is sensitive to deep planting; is not affected by heat, frost or drought.

Ash: The easiest species among hardwoods to raise, plant and transplant. Planted as a seedling one year old or transplanted up to three times. Plants as old as eight years can be planted successfully without balls. Seed is placed in rills seven to twelve inches apart. Where soil is very weedy, large and strong transplants must be used. Planting in holes, on mounds or in furrows. The cleft spade is also permissible in planting yearlings. Trimming is not advisable, except to prevent formation of forks. Transplanting of germs, in June, is quite successful.

Elm: Seeds to be planted in summer (excepting Slippery Elms), just after ripening, in rich nurseries, and to receive very light cover of sand. Seed beds must be sprinkled, and the formation of a crust must be prevented. Seedlings cannot penetrate a layer of one-half an inch of dirt. Usually, transplants three to five years old are used. Fall planting is preferred. Elms stand trimming easily.

Maple: Drills three-fourth inches deep, one inch wide, twelve inches apart. Transplanting takes place when seedlings are one or two years old. Seedlings grow rapidly. Fall planting is preferable. Planting in large holes is best, since Maple cannot form a compact root system. Sugar Maple planted at Biltmore on abandoned fields four years old did very well on North Slopes, in pure stands as well as mixed with White Pine. Maple is easily transplanted, and even yearlings or two year olds might be planted in the open on good soil. In swamps, Red and Soft Maple are preferable. Sugar Maple requires well drained soil.

Yellow Poplar: Very poor seeds, hence broadcast planting. Covering with spent sawdust, instead of dirt, seems advisable. Seedlings transplanted either as germs in first summer or when one year old. Very rapid growth in first and second year. Easily transplanted in holes on suitable soil. Seedlings can be taken in June and July from wood roads to the nurseries, with balls of dirt. Abandoned fields at Biltmore, planted with four year olds did poorly except in northern depressions. Strong soil needed. Compact soil not unfavorable.

Catalpa: The favorite Kansas prairie tree. Very high germinating percentage. Very fast growth in first year. Rills one inch by one inch by twelve inches. Seedling plants one year old are strong enough for planting. Stump plants are preferable. At

Biltmore the top shoot is often killed by frost; it should certainly be cut off after planting. Catalpa requires wheat soil in order to form proper bole, and does not answer in a cold climate. Spring planting in holes or furrows.

Walnuts: The planting of seedlings is only permissible where mice, squirrels and hogs are sure to get the nuts. Very long taps make planting difficult. Best soil needed. Small seedlings are choked out by weeds. Plants one to three years old to be used. Avoid pure plantations! Cover in the nurseries three inches—distance apart four to ten inches.

Hickory: To be treated like Walnut; during the first years, the stems remain very minute while a large tap-root forms. Voles follow along the rows of plants and cut off the roots at a point about one inch below ground. Loose, porous soil is needed.

Cherry: Planted in rills one-half inch deep and eight inches apart. Transplants two or three years old, transplanted when one year old are best for use in the open. Protection from rabbits peeling the stumps is required. Rapid growth in nurseries. Twig tips are usually killed by the first frost since the twigs grow during the whole summer and fall. Pruning required. Black Cherry does well on abandoned fields mixed with White Pine, Pine, Ash, Maple.

Sassafras: Planting of seed in nurseries at Biltmore has been an entire failure. The seeds lived through the first summer but did not begin to sprout. Deep cover required, since cotyledons are kept underground. The removal of the flesh enwrapping the seed (by malting, etc.), seems required before planting.

Paragraph XXXVI. Raising and planting softwood seedlings on open ground.

Yellow Pines: Seeds are covered two-fifths to three-fifths inches deep. Nursery soil to be pressed thoroughly before and after seed planting. Planting of yearlings (from 5,000 to 40,000 per acre) forms the rule. The roots of such yearlings are ten inches long. On sandy soil, cleft planting is universal (with planting dagger). On binding soil, ball plants one or two years old are best.

Recently some foresters began to use transplants two years old which more readily overcome the infantile diseases. No mound nor bunch planting. On very sandy soil Yellow Pines are planted deeper (up to first needles) than they stood in the nursery. A plantation ten years old should densly cover the ground.

Jack Pine (Pinus divaricata) does very well on the poorest sand. It is, however, handicapped by deer; very rapid growth. Pinus rigida crawls on the ground during the first and second year, putting up a strong stem thereafter. Pinus sylvestris (Scotch Pine) is the cheapest that can be planted and the most successful species at Axton. At Biltmore it does exceedingly well on dry south slopes.

White Pine: Quite different from Yellow Pine is the ease with which it is transplanted. Seedlings one year old are very small and apt to suffer from leaves smothering them. Seedlings two years old have been planted at Biltmore on abandoned fields (in holes) very successfully. Transplants three and four years old are usually used. Owing to its greater shade bearing qualities White Pine may be used also for temporary underplanting. Seedlings suffer badly from fungi. White Pine is subject to damage from too-deep planting. At Axton, the best and strongest individuals form a second summer shoot, the buds of which are killed by early frost, so that no top shoot grows in the ensuing year. At Biltmore, the second shoot seems to be safe from frost.

Relative to other White Pines (flexilis, monticola, albicaulis, lambertiana, aristata) no information is available.

Spruce: Nursery rills one inch wide, five inches apart. Transplanting distance usually four by six inches. Slow growth at first. Smallest size that may be used are seedlings two years old. Ball planting best, bunch planting frequent in mountains. Transplants three to five years old are preferable. Plant in holes, never in clefts. Very sensitive to deep planting. Spring planting forms the rule except in high mountains. High atmospheric moisture is a prerequisite for Spruce. Do not trim. Number of plants per acre from 1,500 transplants to 10,000 seedlings. Picea excelsa might replace P. rubens (the former being cheaper), if the resistance to snow-breaks shown by rubens were equalled by excelsa. Plantations twelve years old should fully cover the ground.

Firs: Seed should be planted in fall. Rills close, say four inches; cover, one-half inch. Early growth very slow; lath screens very essential, owing to sensitiveness of youngsters to heat and cold. Transplants five years old are best. Planting on open ground is dangerous; underplanting is very advisable. Species most planted are Abies pectinata, balsamea, concolor.

Larch or Tamarack: The Western, European and Japanese Larch are scattering species, doing badly in pure stands. Growth in early youth is rapid. Seedlings two years old and transplants three years old are preferred for forest planting. The distance of the rills, and the transplanting distance must be comparatively wide.

Seedlings might be cleft planted; but hole planting forms the rule. Fall planting necessary. Larch permits of heavy trimming. Mulch seeds for one week before planting. European Larch does well at Biltmore and in the Adirondacks.

Hemlock: Grows very slowly in youth. Seedbeds require heavy sheltering (under cloth screens). Transplant the two year olds, and plant the five year olds under cover in the woods.

Douglas Fir: Seeds are still expensive; hence transplants four years old are usual, though seedlings two years old are certain of success. Hot-house treatment of seeds secures early and simultaneous sprouting. Plant seedlings in open ground, not under cover. Plantations made near London, England, lose the long top shoots by sea winds; at Axton, they suffer from frost; at Biltmore, the growth is strikingly poor, possibly due to the deficiency in atmospheric humidity. Plants 14 years old are hardly chest high; plants 11 years old only knee high. In all cases the Washington variety is used. Varietas glauca, of Colorado, forms one summer shoot only, grows slowly, and is said to be more hardy.

Red Cedar: Juniperus virginiana: Seeds lie always dormant for one summer. Seedlings two years old are ready for planting. High lath screens in nurseries advisable (Green). Very slow growth. Shade bearing.

Lawson's Cypress: Stands intense shade, resists frosts, suffers from fungi; is well adapted to underplanting.

Paragraph XXXVII. Results of planting experiments with American hardwoods.

For many years, the governmental forestry bureaus of the German Empire have been examining into the merits of some leading American tree species.

Locust and White Pine have been planted so extensively that they are considered to be "naturalized forest citizens."

In a number of instances, the European views fail to tally with the results of American investigations made with reference to the sylvics of our leading species.

A. Fraxinus americana: requirements as in excelsa; stands inundation better—even long ones!

Germination in first spring; no overlying.

Plant seeds in fall, or else in early spring after three days soaking. One year old, one foot high.

Use transplants two or three years old.

Root is a tap-root with many side roots.

Mayr does not advocate its propagation anywhere in Germany.

B. Catalpa speciosa: suffers badly from short summers, often freezing down to ground. Hence frequently spreading growth.

Seeds of high germinating percentage.

Use either seedlings or transplants two years old.

Light demanding, but fond of side shade.

Mice peel at point of differentiation; all game are fond of Catalpa.

C. Juglans nigra: mild, fresh soil required, and long warm summers.

When one year old, strong tap-roots over one foot long; root fibres at end of tap-root tip.

When two years old, the tap-root is over two and one-quarter feet long.

Height growth: 5 years old, 5 feet.
10 years old, 13 feet.
20 years old, 35 feet.

Decidely light demanding; fond of side shade in early youth.

Yellow Pine shelter wood is very good: More shade prevents lignification. In close stands, it is free from branches.

Nuts sprouting late (being dried out) cause shoots to be killed by early frost: Hence pregermination advisable.

Frost hard in sapling stage.

No game or mice enemies.

Plant nuts or yearlings on well-plowed ground, and cultivate. Plant close together, so as to avoid branchiness. Prune lignified branches only, owing to heavy pith column.

D. Prunus serotina: Modest, provided soil is moist.

Light demanding, but does well under slight Pine cover.

Roots many tapped, strong.

Height growth better than that of any European hardwood, save Ash.

5 years old, 6 feet high.
10 years old, 13 feet high.
15 years old, 22 feet high.

Proof against all effects of frost!!!

Rabbits cut and peel (also mice) young plants.

Seed-beds: plant in fall, to avoid lying over, or else soak in water for three days previous to planting in spring.

Use transplants three years old; plant close, to avoid side branches.

E. Acer saccharum: Fresh, sandy loam, or fresh sand; forming stool-shoots on dry soil, and no stem.

Growth quick; light demanding; strong root system.

Forms forks frequently 15 feet above ground.

Height 35 feet, when 20 years old.

Most frost hard of any Maple species. Game and rabbits despise it.

Seeds mature in June, and can be planted at once, but are just as well preserved and planted in spring.

Use seedlings two years old, or transplants, four years old.

F. Acer negundo: Requires strong soil; does not do on dry soil. Growth very quick to start with—up to 6 feet in 2 years, in 20 years 50 feet.

Development of low, branchy crown.

Light demanding, frost proof.

Use seedlings one year old.

Damaged by game and rabbits.

G. Acer saccharinum: Requires strong soil; not clay.

Growth slower than in other Maples, up to fifth year, 20 years old 35 feet high.

Apt to form forks.

Sensitive against frost and drought; requires shade; does best when used for underplanting.

Use transplanted small saplings.

Never plant on open ground!!!

Mayr recommends it only for sugar orchards—not for timber production.

H. Betula lenta: Avoids wet frost dells and poor dry soil; forms tap-root on sand and flat-root on clay.

Height in 5 years 5 feet; in 20 years 36 feet.

Growth bushy to start with, but soon straight, erect and free from branches.

Decidedly light demanding, but fond of side shade.

No more frost-proof than Beech. Late and early frost damages it, especially on wet clay.

Game, rabbits and mice are very dangerous.

Seed-bed should not be dug over.—Peel off the top cover of grass and weeds on humose sand; hoe the soil and then use roller. Plant broadcast, one pound for two square poles; cover by sifting one-twenty-fifth inch of sand on the seeds and roll again with roller; keep Pine branches on the seed-bed until after germination.

Use tall transplants for planting in the open, owing to animal dangers.

Red Birch is said to do well planted with Pine on abandoned fields, further united with natural regeneration of Beech.

I. Hicoria ovata: All Hickories require strong, deep, fresh soil. Not on clay.

Pignut is satisfied with more sand.

Mockernut is satisfied with more clay.

Butternut requires water, more than the others, and stands inundation.

All Hickories require hot summers but stand severe winters; hence continental climate is preferable to sea climate.

Tap-root of yearling one foot long; of two year old plant one and three-quarter feet; hence transplanting after two years very difficult.

Height growth begins to set in from sixth year, and is good then.

Age 5 years, average height 2.4 feet.

Age 10 years, average height 7 feet.

Age 15 years, average height 13 feet.

Age 20 years, average height 20 feet.

Buds open late but shoot is quickly made.

Nuts germinate slowly; hence malting or better repeated sprinkling with liquid manure advisable; many nuts lie over, even for two years. Nuts thoroughly dried lose germinating power.

Malting or "pregermination" advisable.

In the case of Hickory and Walnut, the following recipe for pregermination is given:

"Make a ditch three feet deep and wide; put nuts in the ditch to a depth of one foot; fill ditch with water up to top of nuts; then add a slight cover of straw; then dirt; then horse manure.

"In this ditch the nuts are kept until planting time, when the nuts will germinate a few weeks after planting (in May)."

Plant seedlings one or two years old, or else nuts, on plowed ground. Cultivating advisable.

Late frost is avoided by the late formation of shoots. Early frosts are bad, if seedlings did not have time to lignify owing to late germination.

Avoid planting on open ground; shade is born readily for a number of years!! Straggling plantations often develop after natural or artificial reinforcing with other species.

Young plants suffer from mice. Damaged seedlings should be coppiced down.

J. Hicoria minima: Height growth quicker to begin with than in Shagbark.

At 20 years, however, Shagbark catches up.

Wood much poorer than in Shagbark (more brittle).

K. Hicoria glabra: Like Shagbark; more modest as to soil; more sensitive as to frost (?).

L. Hicoria alba: More sensitive than Shagbark; same rate of growth; does well in the Westerwald, badly in river valleys.

Paragraph XXXVIII. Results of planting experiments with American softwoods.

A. Pinus divaricata: Very modest: Stands frost and drought and does not shed needles.

Root system tap-rooted, many fibred.

Height growth very rapid, several shoots per summer. Better than Scotch Pine.

2 years old, 8 inches high.

5 years old, 5 feet high.

8 years old, 10 feet high.

Game and hares handicap it, still there is strong reproductive power.

Seed one-half pound per square pole; seed has 60% germination; cones fertile from sixth year on.

Use yearlings or transplants two to three years old for the very poorest soil.

B. Pinus ponderosa: Fails absolutely in Germany, probably owing to insufficient summer heat.

C. Pinus rigida: Very modest; does well in salty swamps; suffers badly from snow-pressure.

When 5 years old, 7 feet high.

When 20 years old, 32 feet high.

Growth is very rapid, but from 12 years on P. sylvestris catches up and then keeps ahead.

Diameter growth better than in sylvestris, too.

Strong reproductive power after insects, game, fire.

Very light demanding.

Cones seed-bearing from twelfth year on.

More proof against late frost, more sensitive for early frost than sylvestris.

Less shedding of needles; more danger from game.

Use yearlings, or transplants two years old.

D. Picea engelmanni: likes strong but not wet soil—it is winter frost hard; but suffers slightly from late frosts.

Root system deep, many fibred; not flat.

Dislikes top shade.

Yearling only one to two inches high; two years old four inches high; five years old one foot high.

Height growth always slow, hence easily outgrown, and pure stands required.

Use transplants, five years old.

E. Picea parrayana: Very frost proof, more so than any other Spruce!

Stands wet soil: not exacting.

No top shade.

Root system compact, fine fibred.

Slow early growth, as in Engelmann's Spruce.

Plantations 10 years old average one and three-quarter feet only in height.

Animal proof.

F. Picea sitchensis: Requires moist soil and moist air.

Heat requirements as in P. excelsa.

Soil requirements less than in P. excelsa, growing both on sand and on clay. Not in stagnating moisture, but stands inundation well.

Does well on seashore and on higher altitudes.

Height growth at first very slow; from fifth year on better than in excelsa.

Short branches, slowly dropped; close stand required, fond of forking.

No head shade! Side shade welcome but not required.

Frost and drought only dangerous during first and second year.

Game does not bother it.

Seed-beds of mild, rich soil to strengthen weak seedlings.

Use strong transplants, five years old.

G. Abies amabilis: Plants five years old are still very sensitive against direct insolation and subject to late frosts.

Rate of growth as in A. pectinata.

H. Abies concolor: Spring shoots formed late; resists frost and any other climatic attacks well!

Not exacting as to soil, doing well on Scotch Pine soil of second quality, provided that it be fresh.

Tap-root formed in second year.

Height growth in early youth better than in any other Fir: plants eight years old have average height of three feet.

On good soil even Spruce is outgrown by it.

Wood light (spec. grav. 0.35)!!

Seedlings two years old are fit for planting.

Sensitive against being planted too deep.

Seed-bed treatment as in A. pectinata.

I. Abies grandis: Treatment as in pectinata, which it exceeds in height growth. Soil requirements are the same.

J. Abies nobilis: Frost firm in winter, even unprotected. Late spring shoots help it to escape late frosts.

Stands dry soil; from fifth year on, more light demanding. Forms strong tap-root, and sometimes several branch whirls per annum. Plantation seven years old is three and one-half feet high.

Plant seedlings two years old, or transplants four years old.

K. Pseudotsuga taxifolia: Suitable to any climate, frost proof.

Soil should not be poorer than third-class Pine soil; no dunes; no swamps.

Root tap-root on loose soil, flat on shallow soil or binding soil, showing great adaptibility.

Height growth marvelous!

Age 5 years height 1.7 feet.
Age 10 years height 12 feet.
Age 15 years height 29 feet.
Age 20 years height 45 feet.
Age 23 years height 53 feet.

Diameter, 23 years old, from three inches to ten inches, average seven inches; number of trees per acre 350.

Close stand required to clear from branches.

Light and heat demands as in Picea excelsa.

Snow and sleet throw it over, or break top shoot, the latter loss being quickly replaced by side shoot taking lead.

Game is a very bad enemy.

Use transplants three to four years old.

L. Chamaecyparis lawsoniana: Does splendidly in Germany especially in the Eifel Mountains at 1,500 feet elevation.

Frost-proof; but sensitive in drought.

Exacting like Beech, fond of limestone.

Flat-rooted; suffers from snow.

Shade bearing in early youth; fond of half shade later on; always fond of side shade.

Slow in clearing itself from side branches; forms very close stands.

Very slow growth to start with; one year one inch high; two years four inches high; ten years eight inches high.

Plant seed-beds broadcast. Cover completely. Use transplants four to five years old. Sensitive for too deep planting.

Game are very bad; wood mice peel the stump, or cut the roots.

Less sensitive in late frost because late sprouting; more so in winter frost.

M. Juniperus virginiana: Avoid poor or wet soil.

Seeds lie over, always; seedlings one to two years old are very small and tender. Side shade always liked. Suffering from weeds and grass. Red deer and Roe deer bite and beat it.

Seeds kept in ditches over summer are planted in fall.

Use yearlings and hole planting.

N. Thuja plicata: Desires good, fresh soil.

No swampiness! No dryness!

Top shade or side shade is well liked; do not plant in open ground.

Deep root system.

Height growth slow to begin with, rapid from seventh year on:

Age 1 year; height 1 inch.

Age 5 years; height $4\frac{1}{2}$ feet.

Age 10 years; height 8 feet.

Age 15 years; height 15 feet.

Age 20 years; height 23 feet.

Slow cleaning of bole; very dense thickets required.

Seed bearing from fifteenth year on.

Sensitive for frosts and drought during first years.

Game does not attack it; mice destroy young seedlings.

Seeds are planted broadcast; slightly covered with dirt; sheltered by lath screens.

Strong seedlings three years old (not transplants) are used since the root system is comparatively small, whilst the stem system is comparatively large.

O. Tsuga heterophylla: Requires strong soil; demands side shade, but hates top shade. Cannot stand open situations.

Root is a strong tap-root.

Height growth good from third year on.

Top-shoot-tips are frequently killed by first frost, without any apparent permanent damage!

Use seedlings three years old, raised by broadcast sowing.

Shelter seed-beds well! Sensitive against deep planting.

Mayr prefers heterophylla to canadensis for planting in Germany.

Paragraph XXXIX. Difficulties of natural seed regeneration.

American foresters frequently make the statement that the axe is the best sylvicultural tool inasmuch as its proper use secures a good regeneration free of charge. This statement is misleading. It is true that the density of the stand of the second growth obtainable from natural regeneration is frequently better than that obtained from artificial planting. On the other hand, such a stand can only be obtained under favorable conditions and at a great increase of logging expenses. While the cash expense of natural reseeding might be slight, the actual expense consisting in lessened receipts frequently exceeds the expense of artificial planting. In the primeval woods additional difficulties of seed regeneration lie in the following points:

A. Overaged trees have poor seeds.

B. Interference with the leaf canopy overhead at once invites danger from fire, increased by the debris on the ground, and by the impossibility of battling against fires in the underbrush.

C. In the primeval forest, the age classes are usually mixed in an irregular manner; hence uniform measures for reproduction are out of the question. The forester cannot generalize; he must individualize—a very expensive procedure in the face of low stumpage values.

D. The virgin forest usually contains a mixture of species; the best ones only are removable; the weeds and worthless species are left on the ground; and from this fact arise additional difficulties to propagate the most valuable kinds. To this must be added the difficulty of properly gauging light and shade according to the individualities of the species mixed.

E. In America the lack of a permanent system of transportation necessitates the operations to extend at one stroke over large areas, whilst natural seed regeneration requires the gradual removal of mother trees, in imitation of nature's own way of proceeding, on small and restricted areas only.

As a matter of fact, the lack of permanent means of transportation in primeval woods is the most serious obstacle to regeneration from self-sown seed conscious of its aim and its effect.

F. Natural seed regeneration requires cutting, according to the occurence of seed years and according to the development and requirements of young growth. Hence the axe must be independent from the fluctuations of market or mill requirements, an impossibility in the United States at the present time.

The term "natural seed regeneration" does not preclude artificial help to increase the chances of regeneration. The term merely implies "seeding," or scattering of seed, in the main unaided by man. Man, however, may carefully prepare the seed-bed, by plowing or hoeing or digging, or may carefully press the seeds naturally fallen into contact with the soil; and may protect the seed and the seedlings, at great pains, against external dangers.

Little help is given, where soil and stumpage are, and promise to remain, of small value.

Under the reversed conditions, the expense incurred for natural regeneration often exceeds that required for artificial regeneration.

In innumerable cases, natural and artificial regeneration are locally and irregularly combined.

It might be asserted, that the forest has secured its own regeneration through many millenia, and that it will continue to do so unaided by human activity. Why then, it might be asked, is it necessary or advisable to now offer costly assistance in order to secure natural reseeding of and in a lumbered tract of woodland?

There cannot be any doubt that nature, barring bad conflagrations or heavy pasturage, will start and develop after lumbering some kind of a second growth of forest. As a matter of fact, it is usually at hand, previous to lumbering, in an embryonic or incomplete state waiting for the chance to shoot ahead after the removal of the older trees. This ready nucleus, however, consists as a rule of inferior or worthless species; of specimens crippled by fire, by the fall (accidental or otherwise) of nearby trees, by the logger's axe or foot, by teams and loads passing by, etc. In addition, many members of that nucleus will die when suddenly bereaved of the shelter (against drought, cold, hail, etc.), previously exercised by the old trees now removed.

It must be remembered that a crop of weeds usually follows in the field after the harvest of valuable wheat; in the forest after the harvest of valuable timber.

Such "weeds" are unable to secure for the owner of the land a sufficient rate of interest on the value of the soil and an adequate reimbursement of the taxes due on the soil.

Another moment worthy of attention lies in the poor chances which a grain of seed stands, in nature's economy, to develop into a seedling, sapling, pole and tree. The probability is that only one grain of seed—out of millions of grains—produced by an individual tree during its lifetime succeeds in reaching tree size, replacing it progenitor on the forest floor. The ecologic incidents bringing about this result are far from being clearly understood. Still, it must be the sylviculturist's aim to provide for these incidents, if he desires to replace the old crop, removed at an unnatural rate of rapidity, at an equally fast rate by an offspring resulting from self-sown seed.

If the forester were satisfied to merely remove nature's moribunds, then he might get along with a purely natural regeneration, entirely unaided by human skill.

As soon, however, as his axe creates in the forest an unnatural death rate, the forester is compelled to also secure, by intelligent means, a supernatural rate of birth.

Human aid to natural regeneration should be denied where:

a. The danger from forest fire is such as to render investments in second growth very unsafe.

b. An outlay incurred for protection from fire is not apt to be refunded with interest by the value of the second growth.

That much aid and that much money should be, in all other cases, spent for the purpose of regeneration as promises, in the owner's mind and according to the forester's forecast, the highest relative revenue on the investments made.

At Biltmore, 10% of the annual gross receipts are annually reinvested, to be applied to natural regeneration of the forest.

Sylviculture and finance are continuously at loggerheads. From the business standpoint, however, that Sylviculture is certainly best which proves lastingly most remunerative.

Where and as long as the prospective value of seedlings is small, only a small expense can be reasonably incurred on behalf of their propogation.

Again, seedlings are more endangered by fire than trees. Where, and as long as the danger from fire prevails in the forests of the United States, investments made for raising seedlings are so risky as to be inadvisable.

Paragraph XL. Age of trees fit for natural seed regeneration (Enesar).

The age of perfect puberty depends on species, density of stand, quality of soil and climatic conditions. Generally speaking, it lies about the eightieth year of the trees.

Birch, Alder, Larch and Yellow Pines may be seed-regenerated from their twenty-fifth to thirtieth year on; Oaks, Beeches and Firs from their sixtieth to eightieth year on. Trees of very old age, say over 200 years old, have poor seeds and often defy natural regeneration if occurring in pure, even-aged stands.

Paragraph XLI. Methods of natural seed regeneration (Enesar).

A fixed method is applicable in the arts only where a fixed type of conditions exists. Fixed types rarely exist in primeval woods. Hence the impossibility, from a sylvicultural standpoint, to adopt any fixed European method of seed regeneration for direct application in American practice. A second growth, obviously, presents a more fixed set of conditions (it certainly lacks everywhere the hypermature age classes) than a primeval growth; and, consequently, it allows of a more methodical treatment. In Biltmore Forest methodical treatment is, therefore, permissible; in Pisgah Forest it is not or not yet indicated.

The types of seed regeneration might be considered:

A. According to the relative position of old and new growth:

I. The young growth develops underneath the old growth:

a. Whilst the old growth is left intact (natural seed regeneration by advance growth), or

b. Whilst the old growth is gradually reduced (natural seed regeneration under shelter woods).

II. The young growth develops at the side of the old growth (natural seed regeneration from adjoining timber).

B. According to the size of the units of regeneration, which may be:

I. Compartments, i. e., a cove, a slope, a top or a coherent part thereof, comprising from ten to one hundred acres.

II. Strips, i. e., figures of a more or less rectangular form, in which the length is a multiple of the breadth, the latter not exceeding 500 feet.

III. Groups, i. e., aggregates of growth of a more or less circular form, covering 0.1 to 3 acres.

IV. Patches, i. e., areas covered by the crown of an individual tree, about one one-hundreths of an acre in extent.

The figures given are meant to illustrate, and are not meant to define (in this paragraph as well as in the following fifteen paragraphs).

C. According to the degree in which the soil and the youngest seedlings are directly exposed to the sky:

I. Regeneration without exposure—by advance growth.

II. Regeneration with short, slight, partial exposure—under shelterwood.

III. Regeneration with entire, heavy exposure—from adjoining timber.

D. According to the timing of lumbering and of reseeding:

I. Lumbering precedes reseeding—natural seed regeneration on clearings, namely:

a. On uniformly cleared compartments (cleared compartment type);

b. On cleared strips (cleared strip type);

c. On cleared groups (cleared group type);

d. On cleared selected patches (cleared selection type).

II. Lumbering coincides with reseeding—natural seed regeneration under shelterwood, namely:

a. On uniformly sheltered compartments (shelterwood compartment type);

b. On sheltered strips (shelterwood strip type);

c. On sheltered groups (sheltered group type);

d. On sheltered selected patches (shelterwood selection type).

III. Lumbering follows reseeding—natural seed regeneration by advance growth, namely:

a. With uniform advance growth all over a compartment (advance growth compartment type);

b. With advance growth in strips (advance growth strip type);

c. With advance growth in groups (advance growth group type);

d. With advance growth in selected patches (advance growth selection type).

E. According to the participation of ligneous weeds (bushes, seedlings, saplings, poles and trees of a negative value) in the regeneration:

Totally successful seed regeneration;

Groupwise successful seed regeneration;

Patchwise successful seed regeneration;

Individually successful seed regeneration;

Unsuccessful seed regeneration.

In America, it will be frequently advisable for the forester to merely work toward a "groupwise" or "patchwise" successful seed regeneration.

F. According to the number and according to the distribution of standards left in the regeneration "area": Natural seed regeneration

a. With standards systematically left all over the compartments;

b. With standards left in strips;

c. With standards left in groups;

d. With isolated scattering standards.

The "compartment" types had better be called "uniform" types; the "selection" types had better be termed "patch" types.

Still the terms "shelterwood compartment system" and "shelterwood selection system" having become standard terms of forestal terminology, it seems unwise to throw them aside.

A number of "pure types" may be, and usually are, combined into "bastard forms." Of course, only types more closely related allow of bastardizing.

Bastard forms frequently found in the old country are:

"Advance growth selection" and "shelterwood group" type;

"Advance growth group" and "shelterwood compartment" type;

"Shelterwood group" and "shelterwood strip" type;

"Cleared strip" and "advance growth strip" type;

"Cleared group" and "shelterwood group" type;

"Cleared selection" and "shelterwood group" type.

Modern forestry abroad begins to despise methodical rules, gradually returning to nature with her irregularities. Pure, abstract types of seed regeneration are more and more discarded.

The selection of a method or a combination of methods depends entirely upon the composition of the growing stock found; on local dangers; on local means of transportation; on value of stumpage and prospective value of seedlings.

Where all age classes are mixed irregularly, individual selection is, ceteris paribus, indicated.

Where the age classes or the species appear in groups, the group method is or may be advisable.

In woods simultaneously maturing, the uniform type may recommend itself.

The following paragraphs are arranged to conform with the view point given under "D."

Paragraph XLII. Types in which lumbering precedes N. S. R.

Where lumbering precedes regeneration, the area lumbered must be reseeded from the borders of adjoining woods. With increasing size of the area cleared of timber, the rapidity, the certainty and the quality of regeneration rapidly decrease. The fact that such regeneration is possible on a large scale, is readily proven by object lessons in the primeval woods (Long Leaf Pine; Bald Cypress; Lodgepole Pine; Douglass Fir) as well as in second-growth forests (White Pine in Lake States; Yellow Pine in the south; Spruce in the Karpathian Mountains).

The chances for success depend on:

A. The species, which must have light or winged seeds readily carried about by the wind (many Pines, Spruces, Larches, Cottonwoods, Birches, Yellow Poplar), and which must not require, during their earliest stages of development, the presence of a shelterwood overhead.

B. The coincidence of the compass direction in which the clearing lies from the adjoining woods, with the direction of the wind preferably opening the cones and carrying the seed.

C. The local danger from storm which might tear down, gradually at least, the adjoining seed trees.

D. The condition of the cleared soil and its quality as a ready seed-bed, influenced by the presence of weeds; by the decomposition of the humus; by the degree in which the mineral soil has been laid bare in the course of logging operations; by the grade of the slope.

E. Fires favorable or unfavorable; pasture favorable or unfavorable to regeneration, as the case may be.

F. The frequency of seed years, and the possibility of lumbering during a seed year.

G. The size, the form and the environments of the area cut over.

H. The possibility of preventing undesirable species (Gums, Black Jack Oak) and undesirable specimens, like low-branched weed trees and spreading "wolves," from occupying the area to be regenerated, and the possibility of regenerating all, a few, or only one species.

According to the size of the clearing, we distinguish between:

The cleared compartment type (large areas cleared);

The cleared strip type (narrow belts cleared);

The cleared group type (fair sized groups cleared away);

The cleared selection type (small bunches of trees or merely single trees cut).

Paragraph XLIII. The cleared compartment type.

A. The area bared at one stroke by lumbering comprises between, say, ten and one hundred acres. If the width of the clearing is less than 500 feet, the "cleared strip" type is reached. If the acreage cleared is much in excess of 100 acres, the development of a second growth is very slow, very poor, very doubtful, so that the character of a sylvicultural type is lost. A number (say five) of seed years are required to restock the ground. The bordering woods, from which reseeding is expected, must not offer an unprotected front to the prevailing storm direction.

The regeneration obtained is, naturally, very heterogeneous and contains a great deal of misshapen advance growth as well as of weed growth.

Weeds trees left on the ground might be girdled if belonging to an undesirable species (Beech in Galizia).

A few seed trees might be left scatteringly (if wind firm) in groups or in strips, preferably close to the roads, often consisting of doty specimens without any value.

An usher growth of Cottonwoods, Birches, Sumac, Locust, Sassafras, etc., frequently precedes the second growth desired on the ground.

Fires preceding the seeding, and immediately in the wake of logging, greatly enhance the success of Yellow Pines, Douglas Fir, etc. Yellow Poplar, on the other hand, is checked by the heavy growth of weeds following fires. Stock pasture is of advantage, where it presses the seeds into the soil, and where it checks the weeds.

The clearing should comprise, if possible, only one side of a cove at a time or the lower part of a slope or the bottom of a cove, so as to allow of greater ease in reseeding.

B. Actual application: This type has been adopted,—not confessedly but actually—by the Austrian Government in dealing with the primeval woods of Galizia, consisting of Beech, Fir and Spruce.

The Bureau of Forestry has tried to adopt it, in modified form, for the Minnesota National Forest Reserve and for the majority of its business-working plans (Sawyer and Austin; Weyerhäuser).

Thousands of acres of abandoned farm land all over the Eastern States have been reforested in this manner, frequently against the owner's will.

C. Advantages: The cleared compartment type shows the following advantages:

I. Greatest ease in lumbering.

II. Concentrated operations and concentrated supervision.

III. Few permanent main links of transportation required.

IV. Smallest deviation from the old-time manner of destructive lumbering.

V. Possibility of temporary use of the clearing for the production of field crops benefited by the fertilizing effect of the humus.

VI. Ease of artificial reinforcing and possibility of soil preparation by plowing and by firing; of covering the seeds by pasturage.

D. Disadvantages:

I. Applicability to few species only.

II. Danger of partial or complete failure, especially in clearings covering 100 or more acres, or in case of border trees unfavorably situated.

III. Danger from heavy fires where the soil and the humus is baked by the action of the sun, with heaps of debris left on the ground after wholesale logging.

IV. Second growth consists largely of wolves, and of spreading advance growth and of poles undesirably ramified. Expensive girdling or cutting of seed-bearing weed trees, belonging to a worthless species.

V. The running expenses for protection from fire and for taxes are, to a degree, independent from the quality of the young growth. They are relatively high, and hence absurdly unbearable, if that growth is poor, straggling and very slow to develop, all of which is apt to be the case in this type of seed regeneration.

Thirty years after clearing, the average age of the young growth is not apt to exceed ten years.

VI. Groups of advance growth are almost sure to be destroyed or to be crippled by logging and by sudden change of environments.

Paragraph XLIV. The cleared strip type.

A. The width of the cleared strip is from two to five times the length of the mother tree. When one belt is seeded successfully, another strip is cut into the timber alongside the first belt, and so on.

Soil work is not required, provided the strip is cleared in a seed year. Usually the soil is torn up sufficiently by the removal of a large number of logs snaked or rolled or shot along the strip and over the strip to the nearest road.

One seed year is rarely enough to secure full regeneration of a strip. In the Alps, Pine regeneration takes from twelve to thirty years. On hardwood soil, the weeds are to be dreaded, preeminently so on fertile ground after fires.

It is wise to leave a few wind-firm mother trees scattered over the strip, notably immature specimens of the most desirable species. Less desirable species on the nearby border might be girdled or removed by extending the removal of that species into the bordering forest. In addition, valuable hypermature trees might be withdrawn from the nearby forest.

The cleared strip type does not require a permanent system of transportation of great intricacy, the strips themselves forming the main lines of transportation. The narrow edge of the strip merely is touched, on the valley side, by a road. According to the grade of the strip, sleighs, cables, chutes, donkey engines, etc., might be used to deliver the logs to the road.

At the beginning of operations, the first strip should be made in sheltered localities so as to allow the forest adjoining leewards to remain unharmed by storm.

The strips proceed windwards gradually, the next being cleared when regeneration in the preceding strip is fully secured.

The danger from insects and fungi is small. The danger from fire, to begin with, is great, although not as great as in large clearings to which the wind and sun are freely admitted. Later on the even-aged character of the strip will help to check fires.

Nothing prevents the owner from reinforcing the strip artificially if he thinks fit. Healthy groups of advance growth, formed by desirable species in the belt at the time of logging, might be carefully husbanded. Natural regeneration will set in as well at the side of the belt underneath the bordering mother trees. "Regeneration runs into the old woods." This is a very desirable state of affairs allowing, in the next belts, regeneration to start in advance of cutting. (Bastardizing the cleared strip type with the advance growth strip type.)

B. Actual application: This type of regeneration is locally used in the Tyrolian and Austrian Alps, for Spruce, Larch, Pine. The form of the strips need not be rectangular. It depends on maturity of growth, configuration of soil, danger from storm. The type seems well adapted to present American conditions, requiring, of course, local modifications or bastardations, governed by species and market. Its applicability, however, rests on the existence of some permanent chief arteries of transportation.

At Biltmore, the type is applied, in modified form, for the reproduction of Yellow Poplar and Yellow Pine.

C. Advantages of the cleared strip type:

I. Applicability to many species, to many conditions and to many localities.

II. Concentration of logging operations and of sylvicultural help possible. Cheap logging by donkey engines, chutes, snaking, etc.

III. Many points of attack, at which the season's cut might be obtained, are at the disposal of the forester, if he so desires. Hence great freedom of action.

IV. Comparative safety of the old woods from storm; of the young growth from fire, drought, frost, insects, etc.

D. Disadvantages of the cleared strip type:

I. If the seeding of the strip is not effected soon after clearing, the soil is baked by the sun, weeds are started and the ecological conditions are affected in a manner barring the success of seed regeneration and necessitating artificial help.

II. Border trees are exposed to sun scald.

III. Deer frequent the strips and spoil the young growth.

IV. The soil of the strip—especially of the first strip in a series—is rarely "in heat," certainly not over the entire strip, so that the seeds falling upon it have a poor chance of success. This is the case, preeminently, in the humid mountains where a heavy layer of raw humus covers the ground. A large number of years will often elapse, before the next adjoining strip can be taken in hand.

V. The strips should be cut where the timber is most mature at the time,—and not in a succession merely dependent on the condition of the young growth and on the necessity of proceeding against the prevailing storm direction.

Paragraph XLV. The cleared group type.

A. The groups cut comprise from 0.1 acre to three acres. The form is roundish, oval, square, etc., as the case may be, usually coinciding with a geological feature, f. i., a dell, a spur, a spring-head.

The incentive for group-cutting lies either in the simultaneous maturity of the trees stocking on it, or in the desire to obtain conditions particularly favorable to the reproduction of one of the species appearing in the old timber; or the group, previously stocked with an undesirable species, is to be seeded by a better kind.

B. Actual application: This type has never played an important role in connection with natural seed regeneration. Sylviculturally it seems well adapted to Yellow Poplar, Long Leaf Pine, Lodgepole Pine, White Pine, also to Hickory and Oak.

Where the groups run in the shape of long tongues, parallel at regular intervals, they are termed "coulisses." The coulisses are usually meant for the regeneration of more light-demanding species; the "benches" separating the coulisses for the regeneration of more shade-bearing species.

In Germany, the space formerly occupied by a cleared group is termed a "hole." Where the groups, after reseeding, are gradually enlarged, the cleared group-type is bastardized with the shelterwood group type.

C. Advantages: The soil of the group, thanks to a sufficient amount of side shade, retains its freshness and porosity. It is sheltered from severe winds and severe heat. Species too sensitive for reproduction in larger clearings or strips can be raised in groups. Where the age classes appear in bunches, each bunch can be harvested at its proper age of maturity. No harm or little harm is done to young growth during the logging season.

D. Disadvantages:

I. Operations are scattering.

II. Intricate system of permanent roads required.

III. Groups surrounded by tall timber frequently act as "frost-holes" where young growth suffers badly from early frosts and late frosts in clear nights.

IV. Thin barked trees surrounding the group suffer from sun scald; flat-rooted trees suffer from storm.

Paragraph XLVI. The cleared selection type.

A. In this type, individual trees considered mature are selected for removal, either absolutely singly, or in very small patches formed by neighboring trees.

The clearings made are so small that only shade-bearing species will regenerate thereon, unless the soil be particularly strong.

The cut is so scattering, that the soil is not sufficiently "plowed" by the loggers. Hence it will not act as a ready seed-bed.

In mixed woods composed of many species, only the most valuable kind is usually withdrawn, and the small gaps made are occupied by shade-bearing and often less valuable species.

Beneath hypermature trees, the soil has frequently hardened and defies any attempt of seedlings to establish themselves after logging.

The cleared selection type is almost invariably bastardized with the shelterwood selection type and with the advance growth selection type.

B. Actual application:

In the tropics, Teak, Mahogany, Ebony, etc., are cut by selection, frequently regardless of the effect which logging will have on regeneration.

In Europe, the type is found in the Fir forests owned by farmers; in parks; in protective forests at the headwaters of rivers; on very steep slopes dotted with Larch, in the Tyrol.

In America, Yellow Poplar, Walnut, Cherry, White Oak, etc., are cut by way of individual selection,—but with no regard to reproduction. Also White Pine in the Spruce and Fir woods of the Adirondacks where it never succeeds, withdrawn alone, to reproduce its kind.

C. Advantages:

I. The water-storing power of the soil is generally well preserved under this type.

II. The second growth is never endangered by snow or drought or frost or sleet; the old trees remaining do not suffer from storm or sun scald.

III. Small wood lots may yield a steady annual supply of timber or wood under this type.

IV. The type is well adapted to deer parks.

D. Disadvantages:

I. The operations are very scattering. Indeed, they cover continuously the entire forest or a large percentage thereof. Difficulty of supervision.

II. An intricate system of permanent roads is required, since the axe returns every few years to the same compartment. If the intervals of years are long—say from ten to twenty years—the type is bastardized with the cleared group type or with the shelterwood group type.

III. The type as a means of regeneration, in its purity, is possible only where

a. The compartments contain a mixture of all age classes, with the hypermature classes not too badly prevailing;

b. The species to be regenerated is an intense shade-bearer;

c. The soil is strong enough to allow light-demanding seedlings a chance at surviving a long period of partial suppression.

IV. The species removed—presumably the most valuable species —has reduced prospects of propagating itself, struggling against competing species, the number of its seed trees being relatively decreased.

V. Small chance for reinforcing.

VI. Impossibility of protection against fires under headway.

Paragraph XLVII. Types in which lumbering coincides with N. S. R.

In these types of natural seed regeneration—so-called shelterwood types—lumbering and reseeding go hand in hand, both progressing seriatim, slowly, cautiously. In the pure types, no tree is removed, unless the removal has a distinct bearing—or is expected to have it—on the production of a progeny or on its further development. Seedlings less than five years old usually stand within a few yards of their mothers. This distance is gradually increased—in the course of up to fifty years—until the youngsters do not require any more, or rather despise, the benefit of the parents' presence.

Lumbering operations are carried on—in one and the same limited lot—during a number of years.

Where the mother trees are very rapidly removed, after reseeding, from the proximity of the youngsters, the pure shelterwood types approach the types of cleared compartments, cleared strips, etc.

Where the mother trees are very slowly removed, after reseeding, from the proximity of the youngsters, the pure shelterwood types approach, or bastardize with, the advance growth types.

The chances for success depend on:

A. Sylvicultural talents of the forester in charge and of his staff, also on the size of the ranges.

B. Frequency of seed years and time allowed for the entire operations.

C. Shade-bearing character of youngsters and firmness of parents.

D. Existence of a permanent system of transportation.

E. Configuration.

F. Danger from storm, sleet, fire, animals, etc., locally existing.

G. Size of timber, value of timber, percentage of debris and waste.

H. Marketability of all species or of a few, even of one species only.

According to the manner in which the forester selects the nuclei for reseeding, we distinguish the following types:

I. Uniform type, or pure shelterwood compartment type, where the nuclei are geometrically and regularly distributed over the entirety of a large area (say over twenty to two hundred acres), the nuclei of the entire area being kept, during the entire progress of regeneration, in or about in the same uniform stage of development.

II. Shelterwood strip type, where the nuclei proceed, like advancing skirmishers, in regular military order from the leeward side to the windward side of a compartment (cove, slope, etc.). The nuclei to the leeward are kept in a more advanced stage of growth than those to the windward.

III. Shelterwood group type, where the nuclei are carefully selected, irrespective of geometrical arrangements, merely on the basis of the fitness of the individual spot to act as a seed-bed. The groups are gradually enlarged, increasing in circumference like waves caused by stones thrown in the water.

IV. Shelterwood selection type, where the most mature individuals are everywhere and continuously selected for removal, individually or in small patches, with a view to simultaneous reproduction of the species removed by seeds left on such patches. The patch does not form a nucleus to be enlarged; it is to be retained for a long time in its original size.

Paragraph XLVIII. The shelterwood compartment type of natural seed regeneration.

A. This type is characterized by the uniform manner, in which lumbering and regeneration proceed over large areas.

This uniformity is possible only in somewhat even-aged tracts. Great difficulties are experienced in mixed forests, owing to the difference of light requirements.

The fixed conditions inviting the forester to adopt this type are of a rather rare character, almost absent from primeval woods. The educational value of this type, however, is unparalleled.

B. Actual application: Shade bearers are better adapted to this type than light demanders. Beech is usually treated under this type; Maple and Ash frequently so; Oak largely in France, rarely in Germany; Fir and Spruce in parts of the Black Forest; Pine in the old country only rarely owing to its demands on light.

This "military" type was created by George L. Hartig, toward the end of the eighteenth century. It was considered the ideal type of regeneration up to about 1875. It is now far from being abandoned, maintaining its role as the most commonly used type of seed regeneration, although usually bastardized, in modern times, with the strip and the group type.

C. Advantages:

I. Thorough protection of the soil, of its productive capacity and its porosity.

II. Small risk of utter failure.

III. Large tracts taken in hand at one and the same time.

IV. Methodical, military manner of proceeding which facilitates instruction of the staff of rangers and proper execution of orders by the staff.

V. Mother trees, standing above the young growth in isolated position, yield an extra-increment of high value ("light increment").

VI. Young growth is well protected against climatic adversities.

D. Disadvantages:

I. Difficulty of obtaining a desired mixture of species in the young growth.

II. Necessity for the entire number of old trees to reach maturity at or about at the same time.

III. Even-aged forests are formed by this type which are badly endangered by insects, fungi, storm, snow, etc.

IV. The young growth is badly damaged during the latter stages of logging operations, especially where heavy logs (not wood) are obtained and where the road system is deficient; further on steep slopes.

E. The uniform system, being particularly instructive, deserves a most detailed consideration.

To the mother trees is allotted a three-fold task, viz.:

To seed the "regeneration area."

To protect the young growth from atmospheric hardships and weeds.

To prevent deterioration of the soil during the early stages of the second growth.

Three distinct stages of regeneration must be distinguished, viz.:

I. The "preparatory stage," initiated by a preparatory cutting.

II. The "seeding stage," initiated by a seeding cutting.

III. The "final stage," during which the final fellings take place.

I. The preparatory stage:

a. Purpose: The preparatory cutting intends:

1. To prepare the soil underneath the mother trees for a seed-bed, by increasing the rate of disintegration of vegetable matter. The soil is best prepared at a time when no weeds, but a few shoots of sweet grasses appear here and there. The humus decomposes at the quickest rate on limestone; at the slowest rate on sand and sandstone.

2. To prepare the mother trees for regeneration by allowing them a larger crown space, thus inviting the development of seed buds; further by increasing their stability, so that they may resist the storms when placed in a more isolated position;

3. To remove undesirable species, thus preventing them from propagating their kind.

4. To reduce the volume of the growing stock so as to facilitate the maintenance of a normal growing stock and so as to have less material to remove when the young growth appears on the regeneration area.

b. Duration: The duration of the preparatory stage depends upon the species and the soil. Shade-bearing species found in dense stands need a longer period of preparation than the light-demanding species. On soil rich with lime and in the lowlands, the preparatory stage is much shorter than on sandstone and in the highlands.

c. Area: The area (in per cent. of the entire forest area) to be prepared depends upon the necessities of the market and of the mill (equal annual yield), on the prospects of a seed year, on the frequency of seed years, and on the urgency of other fellings.

d. Trees: The preparatory cutting should remove all sickly trees and all undesirable species. Further, those which have the crowns low down to the ground, which will shade the young growth later on and which now lessen the rate of disintegration of vegetable matter. No dominant trees should be taken out. Near the edge of the compartment it is wise to keep the leaf canopy as close as possible, so as to prevent the influence of drying winds.

e. Marking: The forester himself should mark every tree to be taken out during the preparatory stage. When the wood cutters are not reliable, it is necessary to mark the stumps of the trees as well.

f. Lumbering: Where it pays to dig out the tree by the roots, it is well to do so, because a better seed-bed is the result. Care should be taken that only trees marked are felled, and that those left are not damaged. There is no need to move the firewood and timber out to the roads, if the regeneration area otherwise allows of snaking, wagoning, etc.

g. Pasture: Cattle should not be admitted any more for pasturage during the preparatory stage. Pannage of hogs will be of good advantage. Mice and insects are eaten by them. Hogs break up the net work of roots, leaves and moss forming the soil cover and hindering germinating seeds from catching root.

II. The seeding stage.

a. Time: The best time for "seeding cutting" is a seed year.

The forester should be able to tell from the looks of the buds whether a seed year is at hand. The frequency of seea years depends on the species and on the locality.

If there is no prospect for seeds, the seeding cutting should be postponed, and if a sustained yield is desired, it should be made up by preparatory cuttings, final cuttings and thinnings.

b. The area over which the seeding cutting should extend depends on the area prepared for regeneration, on the length of the period of regeneration, on the periodical occurrence of seed years, on the requirements for a sustained yield and on the available market.

The scarcer the seed years, the larger is the area placed in the seeding stage when a mast year arrives.

The longer the period during which the seedlings require shelter, the larger is the area to be taken in hand at a seeding cutting.

c. Trees: It is wise to take the biggest trees first, as their removal at a later date will result in great damage to the young growth.

If the forester is sure to be able to remove some more trees after the lapse of one or two years, a light seeding cutting is usually best.

During the first two years of their lives the young seedlings stand a great deal of shade, even those of light-demanding species, on fair soil.

The degree of light which should fall on the ground after a seeding cutting, depends on species, height of trees, form of trees and locality.

In the case of tender and slow-growing species, the cover should be close. In the case of tall trees, slight interruptions of the leaf canopy is sufficient.

On good soil, where weeds are to be dreaded, the cover should be denser tnan under the reversed conditions. On a southern exposure, the cover should be dense. Fir, Beech and Spruce require a close stand of the mother trees on strong soil and at high elevations.

Oak and Pine on alluvial sand of average quality should be tapped heavily.

d. The proportion of trees left and trees cut might be gauged by:

1. The distance or space between the crowns. It is very difficult to give any data as to the best distance of the crowns. The form of the crowns is so irregular that it is impossible to ascertain the best average distance.

2. The number of stems which gives a good idea of the cover overhead where yield tables are at hand, if the age and the locality are known.

3. The sectional area of the stems cut and of the stems remaining.

4. The volume cut and the volume remaining.

e. Preparation of soil: Shade-bearing species maintaining the porosity of the soil better than light-demanding species often allow the forester to get along without any preparation of the soil. Under light-demanding species, on the other hand, the hardening of the soil at the time of seed cutting often necessitates the preparation of the ground so that it may serve as a seed-bed. This preparation may consist of:

1. Removal of leaves, weeds or moss.

2. Working the ground by pasturing hogs.

3. Wounding the soil in open spaces, with a hoe.

4. Breaking the soil with a strong plow.

f. Lumbering. All cutting should be done as soon as possible after the seeds have dropped so as to bring them into contact with the ground at once. The wood or timber cut should be dragged to the roads previous to the germination of the seeds. The heavier the seed cutting is, the larger will be the percentage of seeds finding germination. Most of the seeds are imbedded by the steps of the woodsmen.

Advance growth should be removed wherever it appears singly. Care must be taken that remaining mother trees are not damaged by lumbering.

g. Covering the seeds: The covering of the seeds is invariably left to nature or to hazard. It might be advisable, however, to secure a covering artificially with the help of a rake, or by plowing, after the seeds have dropped, or by pressing heavy seeds (nuts, acorns) into the ground with a blunt stick.

h. Fire: After the seeds have dropped, the utmost care must be taken to prevent fire from running through the forest. A fire previous to the dropping of the seed may be advantageous, especially in the case of Yellow Pines. After the seeding, however, it should be prevented.

III. The Final stage.

The removal of the seed trees left takes place during the final stage.

a. Purpose: By the gradual removal of the mother trees, the young forest is gradually lead into a life under changed conditions, until it is ready to enjoy the full influence of sunshine, air and rain.

b. Number of cuttings: The more gradual the removal, the less damage results for the young growth from the logging operations and from changed environments. On the other hand, it is cheapest and best, from the logger's standpoint, to remove the seed trees at one stroke.

c. Beginning: The beginning of the final fellings depends on the development of the young growth. In the case of poor soil, or light-demanding species and of northern climate, fellings should start in the fall following the seeding.

In the case of shade-bearing species, strong soil and southern climate the second or third fall should be waited for. The drier the locality, the quicker must be the removal of the mother trees.

d. Duration: The duration of the final stage depends on species, on quality of soil, on success of seeding cutting, on occurrence of subsequent seed years and on climate. A tender, slow-growing and shade-bearing species allows of a protracted period of removal.

A few trees left in isolated positions are apt to damage the young growth by the reflection of the sun's rays from the bark; this is the case especially in species having a whitish bark (Beech, Maple, Birch, Silver Fir).

e. Marking for final removal: Broad-leaved trees should be marked in summer whilst the trees and the young growth are in leaf.

By the first final felling only small trees shall be removed, after Hess. From the second fall (after the seed cutting) on, the seedlings being stronger at that time, it is wise to take the largest trees.

f. Season: The cutting of the mother trees should take place when snow covers the ground, so as to do the least possible damage to the young growth. Fellings must be discontinued during hard frost. Broad-leafed species should not be cut before leaves are dropped as they will do more damage to their progeny when felled in leaf.

Hess is in favor of cutting in fall, claiming that tbe young growtn at that time is particularly tough and elastic. He does not atiribute much weight to the presence of snow unless it covers the young growth entirely.

g. Stumps and roots: If the trees are dug out by the roots, the force with which they hit the ground is considerably lessened.

In coniferous forests, many parasistic insects breed in stumps, and in that case it may be necessary to dig them out of the ground, or to poison them.

Where the tree is entirely surrounded by young growth, digging should be prohibited.

h. How to fell a tree: The tree to be cut should be thrown onto that place where it is likely to do the least damage—especially onto "blanks." It is wise to throw the crowns of several trees onto the same spot so as to centralize the damage. On the other hand, many sylviculturists prefer to throw the crowns of the trees into the very thickest young growth, claiming that the damage thereby done is considerably less, and that many youngsters will be left undamaged.

i. Standards: In many cases, a few trees are left standing for a second rotation. Such trees are called "standards." Standards of Oak, Pine and Ash are frequently found. They should not be left unless they stand ciose to a road, or unless they are certain to outlast a second rotation.

j. Pruning of mother trees: Low branches which overshadow the young growth heavily should be cut.

k. Transportation of wood: All wood and timber should be moved to the nearest roads as soon as possible after the trees are cut. Speedy removal is especially necessary in coniferous forests, the young growth having little reproductive power. A snow cover might be used to remove the wood on sleds; high-wheeled trucks will answer splendidly on level ground. The method of "roping" used in the Black Forest also saves the young growth. All wood and timber must be removed from the regeneration area previous to the opening of the buds.

l. Pasturage: There is no need to say that the young growth should be protected against pasture.

m. Reinforcing: Blanks should be filled only when the mother trees have been entirely removed. The plants may be taken from dense places where the natural regeneration is complete or, better, from nurseries.

Paragraph XLIX. The shelterwood strip type of natural seed regeneration.

A. This type bears the same ratio to the shelterwood compartment type of regeneration which the cleared strip type bears to the cleared compartment type.

In the shelterwood strip type, as in the cleared strip type, fellings and regeneration begin at the leeward side of a compartment (cove, slope) and proceed gradually against the direction of the prevailing storms.

Heavy-seeded species as well as light-seeded species allow of the strip type. Distinct light demanders, however, defy it on the poorer grades of soil.

The nuclei are laid out geometrically in the shape of strips crossing the prevailing wind-direction at right angles. The most leeward strip is in the final stage; the most windward strip is in the preparatory stage; the middle strip is in the seeding stage, provided that the conditions are normal.

The breadth of a strip depends on species, frequency of seed years, configuration of ground and so on. At a breadth of over 500 feet, the strip type bastardizes with the compartment type.

More frequently, the shelterwood strip type is bastardized with the shelterwood group type.

Regeneration of a cove, slope, tract, etc., under the pure strip type, is exceedingly slow, unless there are at hand a number of "series of strips," all triplets, consisting of a preparatory, a seeding and a final strip.

The first strips are usually made, as in the cleared strip type, in well-sheltered ravines or gullies; or at the windward edge of lakes, fields, young growth; or at the windward edge of storm-firm trees (Oaks), where there is a mixture of storm-firm species with species endangered by storm.

The form of the strips need not be exactly rectangular. In the mountains, the strips usually run up and down the slopes—not horizontal—so as to facilitate the transportation of timber and wood removed from the strip.

B. Actual application: This type is frequently seen in the coniferous woods of the Eureopean moderately cold zone; also in Beech woods and Oak woods.

Like the uniform type, the strip type is not exactly natural. For that reason, the primeval woods do not exhibit any illustrations of the strip type.

C. Advantages: The advantages of the shelterwood strip type are identical with those of the shelterwood compartment type—excepting advantage III. It is especially adapted to small pieces of property, which could not yield steady returns under the uniform type. Greater security from storm is characteristic for the strip type.

D. Disadvantages:

I. Difficulty of obtaining a desired mixture of species in the young growth.

II. Trees at the extreme windward edge of a cutting series obtain an extravagantly high age, whilst regeneration proceeds slowly and gradually against them.

III. Tardiness of a complete regeneration of a whole compartment, slope or cove, where there are only a few points of first attack.

IV. Operations are more scattering than in the shelterwood compartment type.

Paragraph L. The shelterwood group type of natural seed regeneration.

A. Characteristic features.

I. Species: All species can be dealt with in a group system; those endangered by windfall, however, require a modification of the system, or small rotation, or a regular progress of the groups toward the storm danger.

II. Beginning: In the shelterwood system, the nuclei for groups are formed at a time, at which the soil begins to be, here and there, a ready recipient for seed. In the nucleus, two or three trees are cut, to begin with, and a few seedlings soon enter an appearance.

III. Continuation: The young growth gradually spreads out, more or less peripherically, from the nucleus, appearing at the feet of the nearest trees. These trees, in turn, are gradually removed, whilst the groups of seedlings continue to enlarge. Finally one group will flow into the other, and the regeneration will present a waving leaf canopy. The irregularity of the canopy depends on the rapidity with which the groups could be enlarged.

IV. Means of transportation: The type obviously requires a finely meshed, permanent network of transportation. The axe returns to the group under formation periodically, say every three to ten years, during a period of regeneration comprising from fifteen to fifty years.

V. Soil protection: The soil is continuously protected from intensive insolation, and is hence kept in continuous productiveness and water-storing capacity.

VI. Dangers: Protection from fire is very difficult; protection from storm difficult, although easier than in the shelterwood compartment type. Insects, fungi, and snowbreak are not to be dreaded much more than under the selection system.

VII. Lumbering: Mother trees are always felled in a manner forcing them away from the group. Hypermature trees close to the group are extracted at the same time. Lumbering operations are necessarily scattered. Hence the logging expenses and the cost of supervision range very high. The removal (snaking) of the trees cut takes place through the benches of trees left between the groups so that the soil is stirred up continuously within the benches.

The groups should be started, if possible, at the upper end of a slope so that the logs need not be snaked through young growth.

VIII. Artificial help: To start regeneration of a nucleus, and to accelerate the enlargement of a group, mosses, weeds and litter on the ground may be removed previous to a seed year (bastardizing with advance growth group type).

The so-called "hair-dressing" of groups, by which misshapen and branchy growth is cut back, and the wave-form of groups is maintained, may be seen in the Black Forest.

B. Actual application: The shelterwood group type appears to be a type of regeneration sometimes adopted by primeval nature in Beech, Maple, Fir and Pine woods.

As a sylvicultural type, the shelterwood group system has been fathered by Charles Gayer.

It is the most modern type of German n. s. r., applied especially in the natural seed regeneration of Spruce and Beech.

C. Advantages:

I. The type grants the forester the utmost liberty of action, by offering him a large number of points at which to start and at which to continue his logging operations.

II. In mixed forests, the system allows of fostering the most valuable species and of checking the less desirable species or the weed species.

III. The type does not take any sylvicultural chances.

IV. The young growth is well protected against the usual atmospheric dangers.

V. The good qualities of the soil are carefully husbanded.

D. Disadvantages:

I. The type makes unusual demands on the personal and local attention of the manager as well as of the staff, necessitating small ranges and high administrative expenses.

II. Mother trees at the leeward side of an enlarged group are subject to dangers from storm; on the northeast side of a group subject to dangers from sun scald.

III. A large outlay is incurred for logging the trees owing to the scattering character of the operations and owing to the care required in felling and transportation, for the benefit of both young and old growth.

IV. In the case of very large trees, covering by their crowns as much as 500 to 1,000 square feet, the removal of an individual tears too big a hole into the forest and enlarges the group too rapidly at a stroke.

V. The type does not allow of the removal of hypermature trees with proper expedition. They are removed only when the waves of the group begin to touch their feet.

VI. The soil in the proximity of white barked trees bordering a group is scorched by reflected sun rays.

Paragraph LI. The shelterwood selection type of natural seed regeneration.

This type scarcely exists in a pure form. Where it exists, it is invariably bastardized with the cleared selection or the advance growth selection type of natural seed regeneration.

The pure type would imply the immediate development (or rather the simultaneous development) of a seeding growth in the very year (a seed year) in which the individual trees—very irregularly, very scatteringly, on the basis of their relative maturity—are selected for removal.

Where the removal leaves a blank, we meet the cleared selection type.

Where the removal allows an advance growth already at hand to fill the gap, there we meet the advance growth selection type.

The premises for the shelterwood selection type are identical with those for the cleared selection type and for the advance growth selection type.

Paragraph LII. Types in which lumbering follows after n. s. r.

In these types of natural seed regeneration—so-called advance growth types—no tree is removed unless its foot be already surrounded by a young progeny of desirable character which has previously developed beneath the parent's or step-parent's leaf canopy.

The case of exceedingly fertile soil and the case of step-parents having a light leaf canopy excepted, absolute shade bearers only can be propagated by this type. So f. i., Hemlock, Fir, Beech, Maple, Lawson's Cypress, Western Red Cedar.

In the Lake States, White Pine is found as a regeneration formed in advance beneath mature Norway Pines acting as step-parents (advance growth group type).

In the Adirondacks, Spruce regenerates similarly underneath mature Cottonwoods acting as step-parents or, on very fertile soil, selectionwise beneath Beech, Maple and Birch.

Striking it is that species not absolutely shade enduring are, in many a case, loth to be regenerated, as an advance growth, at the feet of their actual parents, whilst willing to be suppressed beneath step-parents of apparently similar density of foilage (Yellow Poplar at Biltmore underneath Oak or Short-leaf Pine; Spruce underneath Cottonwoods).

Species regenerating under their own kin resemble altricial (nidicole) birds; species avoiding parental superstructure might be likened to precocial (nidifugal) birds.

The chances for successful regeneration in these types seem excellent. Still, the following points must not be lost sight of:

I. Advance growth badly suppressed for a long time is frequently so badly crippled that it fails to recover within a reasonable number of years.

II. The advance growth is badly smashed by and during the felling operations, unless the mother trees are pruned and lopped before felling, and unless the timber obtained is carried out either by hand, or on high wheel trucks, or on a heavy cover of snow protecting the advance growth. Under any circumstances, fellings during the perioa of vegetation must be avoided.

III. Advance growth suddenly exposed to the full influence of sun, rain, snow, sleet, etc., is apt to suffer in case of sensitive species.

IV. A minute system of permanent roads is required, the advance growth usually appearing in groups or patches.

V. If the pure types of advance growth n. s. r. were strictly adhered to, a regulation of the annual cut according to the conditions of the market would be difficult to obtain. Hypermature trees would have to be left everywhere—merely because young growth if often slow to form on their feet.

In such cases, artificial preparation of a seed-bed (f. i., by uncovering the mineral soil) seems absolutely required, so as to expedite the formation of advance growth.

If the leaf canopy overhead is opened at the same time by felling operations, the types bastardize with the shelterwood types of n. s. r.

Accordıng to the extent of the area covered by an advance growth of suitable character we distinguish between:

a. Advance growth compartment type of n. s. r., the areas uniformly covered by advance growth measuring from twenty to one hundred acres (rare).

b. Advance growth strip type of n. s. r., the areas uniformly covered by advance growth appearing as strips measuring up to 500 feet in breaath (very rare).

c. Advance growth group type of n. s. r., the groups covered by advance growth having an extent of from one-tenth to three acres (frequent).

d. Advance growth selection type of n. s. r., the young seedlings and saplings appearing in scattered and small patches (very common).

Under "advance growth" is understood an aggregate (small or large) of seedlings or saplings belonging to a desirable species and formed without any human intention or attention, solely by nature, beneath a totally or partially untouched leaf canopy overhead.

Spreading advance growth appearing in bunches or groups can be doctored up with axe and brushhook and machetes, by an application of "hairdressing."

Where the advance growth is not freed, by one single operation, from the superstructure of parents and step-parents overhead, the advance growth types are further bastardized with shelterwood types.

Paragraph LIII. The advance growth compartment type of natural seed regeneration.

A. The type is applicable only where large areas exhibit on strong soil a uniform advance growth, consisting of seedlings, of saplings and possibly of small poles.

Previous to lumbering, the leaf canopy consists of two tiers: an upper tier formed by the parents (or step-parents) and a lower tier formed by the advance growth. Lumbering removes the upper tier entirely and leaves the lower tier intact—if possible.

In the safety of the lower tier lies the great difficulty of the system, especially on rough ground, in handling heavy logs of the superstructure, in dealing with cheap stumpage, in cutting soft woods characterized by small healing power and in the absence of an intricate system of transportation.

Where the upper story of trees consists of say 10,000 feet b. m. per acre, or of more, the ground is literally littered with logs or boles during the logging operations, and the advance growth has but a slight chance to survive the death of its progenitors.

B. Actual application: The type is found, in rare cases, abroad under the misnomer of a modified "selection system," where and when the logger returns for a wholesale removal of mature trees, at intervals of about twenty years, to the same compartments.

The type is also practical where prolific seed years produce, in mild sites and on strong soil, a uniform advance growth in even-aged Beech or Firwoods, without any previous human interference with the leaf canopy overhead (so-called regeneration from a complete-growing stock).

In the United States, compact advance growth is rarely found—possibly so in the case of Tsuga heterophylla. The destruction of the superstructure, however, usually followed by fires, tends to annihilate every vestige of advance growth.

C. Advantages:

Where the system can be carried through, it offers the following advantages:

I. Concentrated logging.

II. Well-preserved productiveness of the soil.

III. Soil never idling, but producing without any delay.

D. Disadvantages:

I. The type is applicable only to intense shade bearers; and these shade bearers are very apt to suffer from sudden changes of environments.

II. The logging expenses are very badly increased in the attempt to save the advance growth from destruction.

III. Under any circumstances, the rapid removal of mother trees inflicts scars upon the young growth apt to serve as entrance gates for fungi and insects.

Paragraph LIV. The advance growth strip type of natural seed regeneration.

A. Advance growth, being a chance product, is rarely found in symmetrical, long-drawn strips. Where the cleared strip-type is introduced, however, a strip of advance growth is often and easily started underneath the border trees joining the cleared strip to the windward. In that case, the advance growth strip-type is bastardized with the cleared strip type.

B. Actual application:

The type is found only in the bastard form just mentioned.

C. Advantages:

I. No expense required for regeneration (unless weeds, leaves or moss are removed).

II. Advance growth is readily saved, where the logs are removed through the adjoining woods.

III. A road system touching the lower edge of the strips is sufficient.

IV. Soil is never laid bare.

V. Little damage from rainfall.

D. Disadvantages:

I. Scattering operations.

II. Type is not applicable to light demanders.

III. Hypermature trees must be left in the woods until the strips, after many years, may approach them.

IV. Points of attack from which cutting may proceed are apt to be lacking, unless the forester is able to maintain a very large number of narrow cutting series, helped by the configuration of the ground.

Paragraph LV. The advance growth group type of natural seed regeneration.

A. In nature, advance growth usually appears in small bunches or in groups, for the reason that there is always a chance for many seedlings to sprout and develop on a spot where light, humidity and soil allow a single individual to make a start alone. In the primeval woods, groups of advance growth formed by shade-bearing species are almost invariably at hand. Even light demanders may form small groups of advance growth in spite of a superstructure overhead, provided that the soil is strong enough to support them.

Such groups, freed from the trees superstructing them, will develop one or a number of saplings which in turn and in course of time may yield one or a few poles promising to grow into trees of a loggable size.

Very frequently the groups are formed not under the leaf canopy of the parent species, but underneath another species acting as a step-parent.

Indeed, step-parents of a rather selfish kind, inimical to the children, are frequently encountered in tree life, handicapping and killing the young progeny thirsting at their feet for light and rain.

The endurance of advance growth living under adverse conditions is at times remarkably great. Fir, Spruce, Beech and Maple may be met grown only six feet high when 60 years old, retarded by parental superstructure.

The pure advance growth group type is frequently bastardized, in Europe, with the shelterwood group type when the forester uses existing groups of advance growth as nuclei to be gradually enlarged, instead of using spots as nuclei for group regeneration on which the soil chances to be in a conceptious condition. Further, when a shelterwood group is forming, advance growth groups are frequently started, under the influence of side light on seedlings and humus, at a goodly distance from the shelterwood group, underneath an apparently heavy superstructure of mother trees.

The advance growth group type pure and simple, however, merely implies the freeing of chance growth from a superstructure. It has nothing to do with the gradual enlargement of a group by ringwise cutting around the group.

The "hairdressing" or groups of advance growth is sometimes commendable.

B. Actual Application: Systematically, this type is nowhere applied in its purity. Accidentally, however, the lumbermen of America happen to employ it in woods composed of Fir, Hemlock, Maple, Beech, etc.

Primeval nature employs this type quite largely (f. i., in Chestnut-oak woods at Biltmore).

C. Advantages: The advantages of the type are identical with those given under C, I, II and IV, in paragraph LIV. In addition, this type may often allow the forester to favor a desirable species of shade-bearing character.

Under sylvicultural care, it renders regeneration an absolute certainty. The trees forming the superstructure frequently happen to be of a marketable size. The type does not require much sylvicultural understanding.

D. Disadvantages:

I. Border trees to the leeward of advance growth are subject to windfall and sun scald.

II. Advance growth groups continue to be badly suppressed, along the edge of the group, by border trees.

III. The logging operations are scattering, and an intricate system of permanent roads is required.

IV. Only intense shade bearers can be properly managed under this type; light demanders found in mixture with shade bearers must gradually disappear from the mixture. The shade bearers will readily form groups of advance growth underneath light demanders; but not vice versa.

Paragraph LVI. The advance growth selection type of natural seed regeneration.

A. This type is usually bastardized with the cleared and with the shelterwood selection type.

The selection by the forester of trees to be cut might be either by single trees or by very small bunches of trees underlaid with a carpet of advance growth covering about one one-hundredth acre of ground.

The logging operations, as in all selection types, are exceedingly scattering; indeed, they ought to continuously extend, as a matter of theoretical principle, over the entire forest.

,Only shade bearers, notably Fir, Hemlock and Spruce, are well adapted to the type of advance growth selection.

The type, like the cleared and the shelterwood selection type, renders the construction of an intricate network of roads necessary. Every tree, so to speak—not every strip or every compartment—must be continuously accessible.

It might be necessary to prepare the soil, in scattered patches, where the layer of humus is too deep, and wnere the soil is so hardened or so covered with weeds as to prevent any chance of n. s. r.

Since the cuttings are comparatively light, the removal of the logs prepares the ground insufficiently for the conception of seed.

Seedlings and saplings in advance growth stand under very heavy shade for many a year, usually in small bunches of a few dozen specimens. Misshapen seedlings and saplings, also those badly damaged during logging operations, should be cut, or coppiced in the case of hardwoods.

B. Actual application:

Wherever the selection type is applied in Europe, it is preeminently applied in the shape of advance growth selection type; especially so in parks, in small farm wood lots and in protective forests.

Usually, every compartment (cove, slope) contains a wild mixture of age classes of trees. The axe returns to a compartment in intervals of from one to ten years.

The Beech, although an intense shade bearer, develops very branchy stems under such conditions (Beech forests in Buckinghamshire, England).

In primeval nature, all or practically all scattering and sparse species are subjected to seed regeneration of the advance growth selection type. The accidental death of trees in the superstructure allows a patch of advance growth found underneath to develop.

Instances: White Oak and Scarlet Oak at Biltmore; also Spruce on hardwood slopes in the Adirondacks.

It is surprising to find that scattering species are regenerated by primeval nature in a type which is considered by the sylviculturist only applicable to intense shade bearers. The explanation lies in nature's long-lasting patience and in her failure to be disheartened when failing in innumerable attempts.

C. Advantages:

I. The type protects the soil, and hence the waters, best of all.

II. It protects the young growth from frost, drought, high winds, insects, sleet and snow.

III. It is particularly pleasing, from the æsthetic standpoint by the unusually large variety of the pictures proffered.

IV. Since every acre of ground continuously retains its leaf canopy, no sunshine, air and rain go to waste in young growth insufficiently covering areas laid bare. At the same time, continuous retention of moisture in the soil allows of greater fertility; hence the quantity of wood fibre annually produced is greater in the selection system than in any other.

V. Small danger from windfall amongst parent trees.

VI. Small danger from fire, since the humus is kept moist continuously. On the other hand, a fire once broken out is extremely hard to stop.

D. Disadvantages:

I. Logging operations are very scattering, and hence expensive.

The fall of individual, large trees amongst the multitude of their companions is very apt to inflict wounds upon them, through which fungi and insects enter readily. (Cancerous Firs of the Black Forest.)

II. A minute network of permanent roads is required.

III. The primeval woods, wherever they represent the selection type, show a preponderance of mature and hypermature age classes. Since the type does not allow of the removal of groups of trees at all, and of the removal of individuals only where they are underlaid by an advance growth, the owner of primeval woods adopting this type is forced to bring heavy sacrifices.

IV. It is very difficult to regenerate light demanders by this type, where they stand mixed with shade bearers.

Paragraph LVII. Regeneration of valuable species from self-sown seed (n. s. r.) with, amongst and into companions of a weedy character.

It is a well-known fact that only a few of the hundreds of seedlings raised (artificially or naturally) by the forester have a chance to develop into poles, standards and veterans.

Dense thickets, consisting of many saplings, are merely required to maintain the fertility of the soil and to prevent, by natural pruning, the young boles from growing into brushy and branchy specimens ("orchard trees").

For the purpose at stake it is immaterial, in a sense, whether the thickets consist of a "mob" of shrubby weeds mixed with a few "aristocrats" hailing from valuable species, or whether the entire thicket consists of "aristocrats." More than that; unless the aristocrat has a value already as a sapling or as a small pole, the "mob" frequently is more conducive to proper soil protection and to proper development of the "aristocracy" into large poles and standards than a purely aristocratic crowd.

The danger, of course, prevails continuously lest the aristocrats might be overtopped and killed by the mob.

A. Wherever the mob consists of even-aged seedlings (not of stoolshoots) of shrubs, that danger is small, shrubs usually exhibiting a slow rate of height growth (Alder; Dogwood; Hazel; Witch-hazel; Rhododendron, etc.).

Stoolshoots of shrubs, on the other hand, frequently grow so fast, so dense and so rank that they are sure to overpower an aristocracy of seedlings of even age.

If the mob promises to easily obtain the upper hand, then it is usually wise to delay regeneration until the shrubbage shows, at a much later year, signs of a declining growth (Calmia); or else to wait until the shrubs allow a deadening (Dogwood); or to fire the shrubbage in heavy seed years of the aristocratic parentage (Blackjack); or to lumber heavily if the shrubs are sensitive and if the aristocrats are hardy (Striped Maple).

Certain weedy shrubs, f. i., Bamboo species, offer periodically a chance for subdual, viz., when death overtakes them gregariously during their own seed years.

Other shrubs are eagerly eaten (or peeled) by sheep, goats or cattle, and might be brought to submission, in the winter following the fruiting of the aristocrats, by heavy pasturage (Mohrodendron for the benefit of Yellow Poplar).

The purpose at stake, in American Sylviculture, for years to come cannot consist in homogeneous regeneration of aristocrats evenly covering the regeneration area; it can only consist in that form, quality and density of regeneration—usually a partially successful regeneration—which the forester considers financially most desirable (compare paragraph XLI E).

The extirpation of shrubs by pickaxe and plow is usually impossible, unless it can be combined with "taungya."

It is often sufficient for increased aristocratic regeneration to break or reduce the humus formed underneath the shrubbage.

B. The battle against weed trees trying to propagate their kind in the forest is usually more difficult to win than that against shrubs since the progeny of weed trees does not stop to compete with aristocrats after the thicket stage. The forester must carefully gauge the chances for a final victory—usually a partial victory—of the aristocrats, footing on a knowledge of their relative height growth and their relative shade endurance.

Weed trees might be prevented from successful seeding by:

I. Deadening or stump peeling.

II. Actual removal (unless resulting in rank stoolshoots).

III. Sudden exposure of young progeny to draught or frost.

IV. Maintenance of a dense humus, or of a dense leaf canopy.

V. Pasturage.

VI. Stopping all logging operations during seed years of the weed-tree species.

VII. Fire.

Any of these remedies will answer on a regeneration area provided that it inflicts greater damage on the weed trees than on the aristocrats, and that the success is fully commensurate to the expense.

A careful choice of the type of regeneration (cleared, shelterwood, and advance growth types in compartments, strips, groups or patches) is, however, the best weapon in the hands of the forester against mobbish usurpation.

The time may come when the forester will avail himself of plagues of fungi, vertebrates and insects in the struggle against weed trees.

Obviously, where the logger, followed by fires, removes every vestige of the aristocracy and every chance for its reproduction on deteriorated soil, there the sylvan battle is lost for the forester before it is begun.

Frequently in nature's economy and ecology a crop of weed trees (Birches, Cottonwoods) intervenes between two generations of aristocrats. This "rotation of crops" resembles that of agriculture, and is hard to explain. Attempted explanations are: Exhaustion of soil in mineral matter required by the previous species. Presence of baccilli, bacteria, fungi, insects, etc., inimical to the previous species.

Paragraph LVIII. Pedagogy of the high forest.

Forest pedagogy or forest tendance, the second part of the sylviculturists' activity, is of little importance in America at the present time since there are no wood crops at hand which might be profitably tended. Forest protection, usually considered a branch of forestry, is merely a branch of forest tendance.

The following operations are here treated under the heading forest tendance:

A. Cleaning }
B. Weeding } Indirectly remunerative acts or investments.

C. Improvement cuttings }
D. Thinning } Directly remunerative acts yielding a surplus revenue.

F. Underplanting }
E. Pruning } Indirectly remunerative acts or investments.

The definitions of the terms "cleaning," "weeding," "improvement cutting" and "thinning" are so indistinct that it is often difficult to differentiate them. Definitions might be based either on the age of the wood crop tended, or on the purpose aimed at, or on the financial side of the tending.

Cleaning and weeding are applied for the benefit of very young growth and usually require an investment.

Pruning, thinning and improvement cutting are applied for the benefit of polewoods or thickets.

Improvement cuttings and thinnings usually furnish a surplus revenue whilst pruning succeeds only in rare cases to be directly remunerative.

Paragraph LIX. Cleaning in high forest.

Cleaning may occur during the seedling stage and the small sapling stage. It implies the removal of saplings forming a shrubby advance growth (wolves); or the removal of undesirable stoolshoots; or the removal of seedlings and saplings belonging to a less-desirable species competing for space in a young forest. In natural seed regenerations, cleaning is particularly desirable. Instances: Removing poor coppice shoots which oppress by faster growth the valuable seedlings of Yellow Poplar. Removing Birch, Fire Cherry, Thorns and Briars in young plantations of White Pine, Yellow Pine and Spruce. Where a regeneration area of strong soil has been burned previous to planting, the competition of volunteer growth is frequently such as to make cleaning necessary. The forester should take care, however, not to extirpate species now of little value, but possibly of a fair future value.

In mixed regeneration, cleaning offers a good means to regulate the proportion of species admixed. The expense incurred for cleaning must be commensurate to the financial effect of the operation. Instruments used are axe and brush hook; also long-handled cleaning shears.

Paragraph LX. Weeding in high forest.

A plant, either herbaceous or ligneous, which has a negative value is a "weed." It might be a cripple of an otherwise very valuable species (fire crippled Chestnut in Pisgah Forest), or it might belong to a species having no commercial value (Rhododendron, Witch-hazel, Black Gum, Halesia, Chinquapin).

Weeding implies the removal of large saplings, poles and trees having the character of weeds. Weeding may take place before regeneration, or after regeneration has been started. It may act incidentally as a preparatory cutting, a seeding cutting or a final removal. It pays only as an investment since the stuff removed has a negative value.

The purpose of weeding might be the extirpation of suppressors of young growth; or an exchange of unhealthy crooked, fire-scalded, flat-headed poles for new, vigorous stump sprouts (Spanish and White Oak at Biltmore).

The term "weeding" is not found in books on Sylviculture; it forms, however, under present conditions often one of the most important and most remunerative sylvicultural acts.

Weeds are either girdled (deadened) or cut.

In the case of weeds having a diameter of over 6 inches, girdling is often preferable, because cheaper than cutting. Moreover, the cutting of broad leaf weeds often tends to merely replace the weed by weed sprouts.

To prevent this, in the case of sapling weeds, crushing shears might be used.

Some cottonwoods cannot be extirpated by deadening. In that case, the peeling of a strip of bark three feet long at a point two feet above ground is advisable. Cutting of weeds in August reduces the chances of their recovery. In the Adirondacks, the weeding of Beech overshadowing Spruce might be advisable, because remunerative.

Paragraph LXI. Improvement cutting in high forest.

The term improvement cutting was introduced into Indian practice by Sir Dietrich Brandis. Improvement cuttings are cuttings for revenue and for partial regeneration, combined with weeding.

An improvement cutting extracts from irregular woods:

A. Hypermature or dead trees still of value.

B. Misshapen immature trees.

C. Species of minor value.

D. Weeds of pole size and tree size.

Essential it is for the character of an improvement cutting, that it is intended to result, on the aggregate, in a surplus revenue. Cuttings, on the other hand, which leave the premises in a materially decreased financial value, can, of course, not be considered as improvement cuttings. Again, cuttings made at a sacrifice, with a view to an increased prospective value of the forest, are "weedings" or "cleanings" which must be considered as investments, like the expenses spent for regeneration.

I. The purpose of improvement cuttings is or may be:

a. A surplus revenue.

b. Improved financial prospects of the remaining crop carried about by:

1. Removal of trees and poles acting as suppressors;

2. Removal of inferior trees and poles acting as competitors;

3. Partial removal of a superstructure on a regeneration area;

4. Removal of less desirable individuals acting as seed-trees.

c. The effect of a preparatory cutting, a seed cutting or a final cutting in thin, irregular woods, without removing well-grown mother trees of desirable species.

d. Reduced danger from fire, fungi and insects.

II. Kinds of improvement cuttings are:

a. Improvement cuttings in primeval woods.

b. Improvement cuttings in culled woods.

c. Improvement cuttings in woods maltreated by fire and pasturage.

III. Marking: Trees and poles to be removed in an improvement cutting must be individually marked by the sylviculturist.

Generalizing rules for marking cannot be given; each tree or pole must be dealt with according to its individual merits and demerits.

The marking by the forester of improvement cuttings is, consequently, a timetaking affair.

IV. Localities: Irregular, thin woods composed of a multitude of species deserve improvement cuttings.

The local market must allow of the—at least partial—utilization of suppressing, competing, superstructing and less desirable individuals.

Paragraph LXII. Thinnings in high forest.

Thinnings proper are practicable only in dense and fairly even-aged groups or woods, always under the proviso that a permanent road system and a nearby market allow of a remunerative outcome of the act. In Pisgah Forest thinnings are out of the question as the woods are thin enough. At Biltmore, thinnings are made where polewoods of Yellow Pine occupy abandoned fields. Up north, from the merely sylvicultural standpoint, thinnings are possible in the Jack Pine woods, in Balsam thickets, on Black Spruce slopes, in Lodgepole Pine thickets, etc.

For many a year to come the American forester will have little opportunity to make any thinnings.

A. Purposes of thinnings:

I. To develop the log diameter of large saplings and poles at a time at which the log axis has been obtained.

II. To increase the volume increment per acre.

III. To increase the quality increment of favorably predestined mess-mates.

IV. To reduce the danger from forest fires (dead and dying trees), insect pests and fungi plagues.

V. To remove cripples and wolves.

VI. Early financial returns.

VII. Reduction of investment.

VIII. Shortening of the rotation by feeding a lesser number of mess-mates on a relatively larger amount of food (viz. moisture, heat, light, mineral matter, etc.).

IX. Regulation of the relative proportion of species in mixed pole woods.

B. The season for thinning depends upon local climate, seasonable prices of labor, advisability of peeling and intensity of thinning. The season usually selected for thinning in Europe is the late winter when the main cuttings are completed.

C. The time for thinning. Thinnings should begin in the late thicket stage and should be repeated, to begin with, in five-year intervals, say from the year thirty to sixty. Thereafter the intervals are increased up to the year eighty or ninety. A preparatory cutting, although conducted like a thinning, is no thinning, since its purpose is regeneration. Thinnings stop at the end of the pole stage. Where poles are non-salable, for instance, in European mountain districts and almost everywhere in America (excepting Biltmore Estate), thinnings cannot be made.

D. The material supplied by thinning may consist of firewood, pulp wood, mine props, fence posts, telephone poles, hop poles, hoop poles, tool handles, bolts for spokes, locust pins, tannin wood, etc.

In European practice the number of cubic feet obtained by thinnings during the course of a rotation per acre equals one-quarter or one-half of the number of cubic feet obtained by the final cut. Heavy thinnings, as practiced in Denmark, are said to yield as many cubic feet in the aggregate of a rotation as the final cut.

The tool used for thinning is invariably the axe.

E. Kinds of thinnings: The old doctrine was: "Thin early, frequently, moderately!"

This rule has been gradually abandoned during the past twenty years. The method of thinning naturally differs according to the purpose of it. William Schlich distinguished between quality thinnings, made to improve the timber quality of the trees left; and quantity thinnings meant to result in the maximum production of wood fibre per acre per annum.

If left alone, a dense thicket grows slowly only, the food being subdivided among a large number or messmates. Toward the beginning of forestry, sylviculturists were satisfied with thinnings burying the dead and moribund trees. Later on, thinnings were extended into the suppressed classes. The European experiment stations are now deeply engaged in working out the "best" method of thinning. Obviously, no method can be best for all sorts of species and for all sorts of local conditions.

I. The experiment stations distinguish between:

Grade 1. Light thinnings, removing the dead or dying.

Grade 2. Moderate thinnings, removing the dead, dying and suppressed.

Grade 3. Heavy thinnings, removing also the condominating trees, or such of them which are not absolutely essential for the maintenance of the main leaf canopy overhead.

Grade 4. Very strong thinnings, placing a limited number of dominating and predominating trees in a free position.

Results so far published allot the maximum volume production (exclusive of branches) per acre to Grade 3. All these four grades might be characterized as "thinnings from below" (Eclaircies par le bas).

French silviculturists are advocating, on the other hand, "thinnings from above" (Eclaircies par le haut).

The Frenchmen, as a matter of principle, leave alone the suppressed lower stems, protecting by them the quality of the soil as well as the clearness of boles within the predestined class. In addition, they relieve the tension, friction and struggle for food amongst the dominators by culling out the worst developed dominators, or a percentage of those dominators which stand too close together, and which have, consequently, one-sided crowns.

The objection to the French method lies in the following points:

a. Material without increment is left on the ground.

b. Weaklings and dying trees left increase the dangers threatening the forest.

c. Greater difficulty in marking trees to be removed.

However, where quality increment is at stake, the French method seems highly advisable.

III. Radically different from the systems of thinnings heretofore prevailing are the revolutionary views proffered by Borggreve, the "Bryan" amongst European sylviculturists.

Borggreve thinnings interfere or remove only the predominators and dominators—the biggest poles—closest to the best log size. Such thinnings begin only at the year sixty of a woodlot; they withdraw every ten years the largest one-seventh of the stems containing about one-quarter of the total volume.

Of course, high and early revenue is secured by such practice. On the other hand, the trees removed are those growing at the best rate of interest. (From the sixtieth year on 90% of annual secretion in a woodlot is supplied by the 40% (in number) of the largest trees).

The advisability of a Borggreve thinning largely depends on the reproductive power of a wood thus "maltreated." In the case of Yellow Pine and on poor soil, the reproductive power of a wood seems too small to allow of speedy repletion of the growing stock and of its leaf canopy. Much "food" goes to waste after Borggreve thinnings. In the case of White Pine and Spruce, the danger from storm and sleet after Borggreve thinnings must be badly dreaded.

IV. Wagener, at the year twenty-five of a forest, makes a thinning called "crown-free-cutting," surrounding the crown of each predestined tree with an air space two and one-half feet wide. Dominating trees left should stand seven yards apart after the Wagener thinning. Suppressed trees are not interfered with. Such cuttings are much heavier than Borggreve's. At the year twenty-five the bole of the dominators is not fully developed. Underplanting takes places at the same time. The dominators left stand in an orchard-like position and show a very rapid diameter growth. Only one log or so is expected to be obtained from the bole; it is obtained, however, within an extremely short rotation.

Obviously, for coniferous woods exposed to storm and of poor quality if wide ringed, the Wagener system is out of the question. The Wagener thinnings, unless they result in a heavy growth of adventitious branches, might be used to advantage for Black Walnut, Black Cherry and Oaks.

V. In mixed forests such species as reach maturity during the pole stage might be removed by way of thinnings; f. i., Locust and Sassafras from a pole wood of Yellow Poplar; Hickory when reaching spoke-bolt size from a mixture with Oaks; Chestnut when reaching telephone pole size from a mixture with Oaks, Black Gum and Yellow Poplar.

Paragraph LXIII. Pruning in high forest.

A. The object at stake might be:

I. Production of logs free from knots,—especially free from dead knots. Live or sound knots measuring one and one-quarter inches in diameter affect the lumber price only slightly. The prevention of dead knots is, therefore, most important. No topshoot is formed without side shoots, and no section of a tree bole is free from branches and free from branch knots. Hence the advisability of pruning the boles of such species which develop branches of large diameter and of great persistence when dead. Branches (excepting adventitious branches) invariably start from the central core.

II. Increased height growth.

III. The production of cylindrical boles of high form figure (Pressler's law of bole formation). Obviously, "II" and "III" are obtained only by removing live branches.

IV. The reduction of the shade falling on a young, promising undergrowth.

V. The reduction of danger from fire in coniferous woods close to public roads.

B. Species: Hardwoods suffer less from the removal of green branches than softwoods. Green branches of over five inches in diameter should not be removed at all, except in case "IV," owing to the certainty of subsequent disease.

Oak heals the wound inflicted by pruning best; Ash is likely to split; Maple is slow in closing a wound; Birch soon shows disease; Yellow Pine covers the wound quickly with rosin.

C. Actual European practice:

The practice restricts pruning to the case "I" and within case "I" to:

I. Dead branches.

II. Polewoods forty years to sixty years old.

III. Limited numbers of poles (say 100) per acre, namely, to the specimens presumably predestined to reach the end of the rotation.

Pruning extends to a height reaching up to forty feet, is done by help of ladders, of a climbing apparatus (not climbing irons) or of saws attached to very long poles. The best saw is the "Alers" construction.

In France, sharp, curved blades are preferred to saws, since they produce a smoother cut.

The branch is cut off as close to the bole as possible. Large branches are cut off in sections to prevent the bole from being scarred. In the case of broad-leafed species and in the case of live branches, large wounds are always tarred. Tarring in spring is impossible.

Expense at Biltmore for pruning Yellow Pine to a height of 16 feet is two cents per tree.

The best months for pruning are the months at which the sap is down.

The advisability of pruning depends largely on the prospective price—difference between clear lumber and knotty lumber.

Pruning at a late date, say 20 years before cutting, is of no use. Theoretically it is best to remove dead branches in the year of their death.

Where pruning is practiced, natural pruning produced by dense planting and hence dense planting itself might be spared, a proposition which cannot be generally indorsed.

Literature: Translation of DeCourval by Massachusetts Forestry Association.

Paragraph LXIV. Underplanting in high forest.

An upper story of high forest might be underplanted during the pole stage either artificially or by natural seed regeneration. In the latter case, weed species may answer the purpose. Underplanting may improve the timber quality of the upper growth. It usually does improve the productiveness of the soil.

Frequently the purpose at stake in underplanting is that of fully utilizing the productive capacity of the soil and of the atmosphere which is not entirely used by the upper story of growth. In that case, underplanting cannot be considered as a method of forest pedagogy.

A. The species to be underplanted are, notably, light demanders; for instance, Yellow Pines; Oaks; Hickories; Larches; Yellow Poplar, etc. In the primeval woods, Long-leaf Pine, Yellow Pine, Yellow Poplar, etc., show a natural undergrowth.

In practice, the wood to be underplanted is 40 to 60 years old. Heavy "thinnings from below" precede underplanting.

B. The species used for artificial underplanting are shade bearers and, if possible, soil improvers, notably Beech, Hard Maple, Fir, Lawson's Cypress, White Pine, Chestnut, Hemlock, etc.

Spruce is now disliked for underplanting, since it unfavorably affects the growth of the upper story. Seedlings one or two years old are commonly used for underplanting. Dogwood, Black Gum, Witch Hazel, Chinquapin, Witch Hopple, possibly Kalmia and Rhododendron might be used for underplanting where mere soil protection is desired.

The primeval hardwoods of the Alleghanies are frequently and densely underplanted with a low jungle formed by Ericaceae.

Paragraph LXV. Key to the Forms of High Forest.

That general condition of a forest is termed its "sylvicultural form" which is brought about by its type or types of past regeneration, hence by its display of age classes and by the arrangement of the species exhibited.

The treatment alloted to the "form" by the forester, provided that it is a systematic treatment, is termed its "sylvicultural system."

The multitude of forms found in primeval nature is innumerable, since the "molds" from which the forms are cast, vary indefinitely with every wrinkle of the topography and every variation of the climate.

Man's interference has tended—at least temporarily—to further increase the multitude of forms.

It is a hard task to differentiate amongst this huge collection of forms and to arrange the collection into "orders," "families," "genera" and "species" composing it.

A priori, two great groups of forms might be singled out, namely "*primeval forms*" the product of unbiased nature and "*second growth forms*," the product of nature influenced by man's interference. This human interference might have been of a character utterly disregarding sylvicultural ends ("culled forms"); or human art might have tried, successfully or unsuccessfully, to lend a helping hand ("cultured forms").

The manner in which the various age classes of the forest are mixed within the "orders of forms" is of paramount interest. From this manner of mixing depend:

I. The manner and the possibility of remunerative lumbering.

II. The type method and the expense of regeneration and pedagogy.

III. The dangers from insects, fungi, fire, storm, etc., threatening the forest.

The functions of the mixture are so all-important in forestry, that the synthesis of the age-classes must serve as a main criterion in the construction of a key to the sylvicultural forms.

It must not be forgotten, however, that age differences of, say, 20 years are very conspicuous during the seedling, sapling and pole stage of the forest; whilst the keenest eye cannot detect these same differences in an old tree forest.

In mixed forests exhibiting a large variety of species the analysis of the form presents particular difficulties. Such is the case by far more frequently in primeval than in culled or cultured high forest. Sometimes a distinct form of a minor, scattering species appears to be "grafted" upon a distinct form of one or several major, gregarious species ("grafted forms"). Where two distinct forms in mixture occupy more equal shares (not minor and major shares) in the aggregate display, we may speak of "wedded forms." "Husband and wife, though distinct individuals, unite for a life in a household of their own."

A. Primeval forms of high forest.

I. Characteristic for all primeval forms is a relative preponderance of the hypermature age-classes (veterans); a relative deficiency of the youngest age-classes (seedlings, saplings and poles); the presence of a large number of dead, decaying or unsound specimens only temporarily excelled in the "culled forms;" a large number of dead corpses of trees spread flat on the ground; irregular confines of the parts composing the aggregates; irregular composition of such parts by age-classes and species, many of which may be weeds; usually a heavy layer of humus on the ground; usually the presence of a few strikingly large and spotless trees overtowering their neighbors; absolute lack of permanent means of transportation.

II. Subdivision of primeval forms of high forest.

According to the relative share held by species of "weed trees" in the mixture of species composing them, the primeval forests might be subdivided into pauci, multi and omnivendible forests. Primeval woods, in which only 10% of the timber species command a value, might be called "paucivendible"; at 50%, the term "multivendible" and at approximately 100%, the term "omnivendible" might be applied.

The vendibility of the members composing the forest, whilst it controls the possibility and the manner of its sylvicultural management, does not influence, however, the actual display of the forest in the slightest degree.

It will be best, consequently, to subjoin the viewpoint of vendibility to the viewpoint of actual composition of the forest as displayed in the size of its composing parts—notably of its age-classes.

Thus we arrive at:

a. A selection form, where the age-classes raised are mixed by trees or small patches—a very uneven-aged form;

b. A group form, where the age-classes raised are segregated in groups occupying from one-tenth to four acres;

c. A compartment form, where the age-classes raised are segregated in large, coherent areas (coves, slopes) covering from twenty to one hundred acres—a very evenaged form of forest.

The epideta "paucivendible", "multivendible" and "omnivendible" added to the terms "selection form", "group form" and "compartment form" readily explain, in crude lines, the sylvicultural as well as the economic display of a primeval forest.

The groups or the compartments often show a sprinkling of huge trees known as "standards", having a much higher age and frequently belonging to a species different from that or those forming the main growing stock. Instances are:

Yellow Poplar standards in Beech compartments;

White Pine standards in Balsam compartments;

Yellow Pine standards in Oak groups;

Cuban Pine standards in Cuban Pine groups.

Long-leaf Pine standards in Cuban Pine groups.

Naturally, where the standards belong to several age-classes and do not form a distinct age-class by themselves, we merely meet a selection form.

Standards in primeval woods are frequent enough to call for the singling out of a fourth form, namely:

d. A standard form, which might be again subdivided into:

A form of standards over groups;

A form of standards over compartments.

A variety of the latter subform found in the Chaparal thickets of California and in the Calmia thickets of North Carolina might be termed "form of standards over paucivendible compartments."

The two-storied high forest is often formed by two or more distinct species appearing in distinct forms. It had better be considered as a combination of forms, one form being grafted upon another (f. i., multivendible compartments of Douglas Fir grafted upon the paucivendible selection form of Hemlock); or one form being wedded with another (f. i., multivendible group form of Long-leaf Pine wedded with paucivendible compartments of Black Jack Oak).

The term "two-storied high forest" properly applies only to a permanent combination of two tiers of trees (representing one or more species), each tier emanating from regeneration of the compartment type of n. s. r. It is a compartment form wedded with a compartment form.

III. Treatment of primeval forests:

The only treatment required is of a protective, not of a sylvicultural character.

As long as the forest retains its primeval display, unhampered by human interference, the regeneration of the primeval selection form is of the cleared, shelterwood or advance growth selection type;

the regeneration of the primeval group form is of the cleared or advance growth group type; and the regeneration of the primeval compartment form is usually of the cleared compartment type.

Obviously, with the beginning of logging operations the "primeval forms" are gradually, piece by piece, changed into "culled forms," the display of which largely depends on vendibility and on fires.

Rarely only the primeval forest enters at once or directly into a cultured form (Pisgah Forest of the Biltmore Estate; Ne-ha-sa-ne park; government forests in Galizia) without passing through the stage of "culled form." In the large majority of cases, the primeval woods pass through "culled forms" into "cultured forms," in the course of generations of men and of trees.

B. Culled forms of high forest:

I. Characteristic for the culled forms of high forest is the absence of mature or maturing trees belonging to a desirable species; the preponderance of weeds, unsound trees, undesirable species and of trees and poles badly crippled by the logging operations. Only diseased trees or relatively small trees of the desirable species are left to seed the ground.

Advance growth is invariably spoiled where the trees are omnivendible or multivendible.

Characteristic for the culled forms is, further, the presence of large amounts of debris and of a parched humus.

As a rule, the culled forms show death and scars due to forest fires.

Frequently, the culled forest displays an entirely new assortment of the species composing it, the previously prevailing species having been removed by logging. It is more "mobbish" than the primeval forest.

II. Subdivisions of culled forms of high forest:

The culled forest is usually more uniform than the primeval forest from which it emanates, owing to the uniform character of the logging operations. Still, the compartment form, group form and selection form originally exhibited are usually retained.

In the compartment form and in the group form a few worthless trees or veterans left standing and continuing to live frequently remind on the "form of standards in high forest" or on the "form of underplanted high forest." (Compare C, II, b, of the same paragraph.)

III. Treatment of the culled high forest:

Where fires are kept out, the chances for seed regeneration are good—unusually good—owing to the condition of the seed-bed and to the unlimited food supply available for the seedlings.

In the case of Yellow Pines, light fires seem even helpful to n. s. r.

Since the valuable species form, however, the minority amongst the seed-trees, the worthless and less valuable kinds usually prevail in the young growth formed after culling. Cleaning and weeding are required to improve the prospects of the minority composed of noble species. Besides, improvement cuttings are indicated in the culled forms: "The culled form is *the* form requiring improvement cuttings."

The "aristocrats" frequently return only to the regeneration area after a score or two of years, the rash "mob" then acting as nurse-trees or as ushers.

Where heavy and extensive fires have swept the culled forest originally consisting of exacting species, patient waiting alone can secure conditions more favorable to aristocratic regeneration. Fires frequently convert a high forest of hardwoods into a coppice forest.

The younger age-classes suffer more from fire than the older age-classes. A fire-swept, culled forest is deficient, at least temporarily, in seedlings, saplings and small poles. A few years after a fire, the culled forest often displays the features of the underplanted form of high forest (Par. LXV. C. II. b.) or of the coppice-under-standard form (Par. LXXIII).

C. Cultured forms of high forest:

I. Characteristic for the cultured forms of high forest is great uniformity; lack of hypermature, unsound and misshapen aristocrats; lack of weed-trees; lack of coppice shoots; complete cover overhead; multi- or omni-vendibility; permanent means of transportation.

The cultured forest does not require weeding or improvement cuttings for the reason that cleanings and early thinnings have prevented the development of weed-trees and wolf-trees, whilst the hypermature veteran has been removed long ago.

If the culled form is "the form of improvement cuttings", the cultured form might be termed "the form of thinnings".

II. Subdivisions of cultured high forest:

a. Main cultured forms of high forest:

1. Even-aged cultured forms, when the age-classes mixed within a compartment differ by up to 25 years.

aa. Form emanating from the cleared compartment type of n. s. r.

bb. Form emanating from the short-time shelterwood compartment type of n. s. r., the periods of regeneration not exceeding 25 years.

cc. Form raised by planting seeds or seedlings over whole compartments.

dd. Form raised by underplanting seeds or seedlings over whole compartments, followed by (gradual) removal of the superstructing trees within less than 25 years.

2. Uneven-aged cultured forms, when the age-classes mixed within a compartment differ by over 25 years.

aa. Form emanating from the long-time-shelterwood compartment type of n. s. r.

bb. Form emanating from strip types, either restocked by n. s. r. or by planting.

cc. Form emanating from group types of n. s. r., or from planted groups.

dd. Form emanating from selection types of n. s. r.

b. Auxiliary cultured forms of high forest:

aa. Form of standards in high forest, when a limited number of trees are left to grow amongst and with the young growth for a longer or shorter number of years.

The standards might be left either in scattering groups or individually scattered over the second growth. In the latter case, only storm-firm species will answer. It is wise to leave the standards in the proximity of roads so as to allow their removal without inflicting damage on the young growth. Species well adapted for standards are: Yellow Pines, Larches, White Oaks, Yellow Poplar, Black Locust, Hickory, Walnut, Black Cherry. Shade-bearers and flat-rooted species will not answer the purpose.

It is unwise to leave standards unprepared by preceding cuttings for the life in the open. Standards set suddenly free will cover themselves rapidly with adventitious branches, will grow stag-headed, will suffer from storm and sleet, and will die without yielding the results for which they were left.

Where the standards shade the young growth too badly, it may be necessary to remove their lower live branches.

The number of standards left per acre does not usually exceed 25. Very good soil and short rotations allow of an increased number. Standards may be, but need not be, of the same species which forms the undergrowth.

Where the standards do not belong, approximately, to one and the same age-class, there the standard form bastardizes with the uneven-aged forms emanating from the group-type or from the selection type of n. s. r.

bb. Form of two-storied high forest, when an upper and a lower leaf canopy is maintained in distinctly separate tiers.

Species adapted to form the lower leaf canopy are: Beech, Hard Maple, Black Gum, Firs, Hemlocks. The species in the upper story had better have a light-demanding character. The form is created by raising a polewood (even-aged) of Yellow Pine, Oak, Hickory, Larch, etc.; by early and heavy thinnings from below; by very heavy thinnings after the completion of the principal height growth (year forty to sixty); and by planting at the same time either seeds or preferably seedlings of shade-bearing species. Should the undergrowth catch up with the upper growth, either the one or the other must be removed. The undergrowth preserves the fertility of the soil by thorough shading, by the formation of a mixed humus and by increased leaf-fall. It improves the bole-quality of the upper growth, the crowns of the lower growth holding the boles of the upper in close embrace. In addition, it prevents any part of the timber-producing factors of the locality (atmosphere, light, moisture, soil) from lying unutilized. Usually the undergrowth produces firewood, the upper growth timber.

The so-called "Seebach's modified high forest" has Beech in the upper as well as in the lower story. The lower story is obtained from self-sown seed of the upper story after very heavy thinning. Under and upper growth are finally utilized in the same year or in the same period of years.

III. Treatment of cultured high forest.

Regeneration in the cultured form of high forest takes place in any of the types of n. s. r., or by planting seeds and seedlings. As a rule, natural regeneration is now combined with partial planting. Cleaning and thinning are usually indicated, whilst, as stated, weeding and improvement cutting are not required.

Paragraph LXVI. Critical remarks on the forms of high forest.

A. Attitude of the investor:

It is almost amusing to observe the difference of attitudes which the statesman, the lumberman and the forester show with respect to the terms "primeval", "culled" and "cultured" forests.

Still, all of these forests are justifiable, at least temporarily, and usually justified by the economic conditions evolving them.

I. The primeval forest seems to be the "forest in economic stagnation." Still, fortunes have been carved by many investors, buying and retaining primeval forests for their own benefit and incidentally for the benefit of later generations of men. With every parcel of primeval forest destroyed, the value of the balance left increases in estimation and in actual usefulness.

Sylviculturally, no forest requires a more minute and more painstaking treatment than the primeval forest, when its conversion into cultured forest is at stake. Still, the small price obtainable for its products defies any attempt at a remunerative outcome of heavy sylvicultural outlays. What is the use of safeguarding or producing a second growth, by sylvicultural acts, which is devoid of any prospective value, or which is of a value inferior to the expense required to safeguard it or to produce it?

Thus, sylviculturally as well as financially it seems very frequently best to leave the primeval wood unattended, unregenerated, unconverted, for the time being.

II. The culled forest usually exists in localities where timber has a higher value than in the primeval backwoods.

Indeed, where the culling of the forest has made great progress in a state or in a county, there the culled forest is getting rapidly ripe for sylvicultural treatment.

Heavy culling merely proves a high range of stumpage prices, fostered by a near-by market and by good means of transportation.

Where the forest has been culled only of decidedly mature trees, there the chances for good results are bright, financially as well as sylviculturally.

The attitude which the owner of culled forests adopts towards sylvicultural investments, necessarily depends on a diagnosis of the future of the lumber industry appealing to him.

III. The cultured forest is still a rarity in the United States, and will continue to be a rarity during our lifetime.

Imagine for a moment, that the famous Black forest of Germany were suddenly transferred, with its fine Spruce woods, its splendid roads and its skilled laborers, into the heart of the Adirondacks! Would it be wise, financially, to continue its sylvicultural treatment as inaugurated in Germany?

It certainly would; the logs salable in the Black Forest are also salable in the Adirondacks at a good profit. And a network of splendid roads would tend to cheapen transportation by exactly that many cents per standard, which the stumpage itself would gain per standard.

On the other hand, that same Black Forest transferred to the Pacific coast—say into the Olympic mountains—would certainly prove a financial and therefore a sylvicultural failure.

The better it pays to cull the forest, the closer at hand is the time of the cultured forest.

It must be kept in mind, however, that the change from the culled to the cultured forest requires, aside from a market for the products obtained and from the willingness of the owner to embark in sylvicultural investments,

a. Investments in permanent means of transportation;

b. Relative safety from forest fires;

c. Time.

Wherever the woods emerge in a decrepit condition from the primeval stage after reckless lumbering, heavy fires, unlimited pasturage, there the adoption of a system will be found necessary after scores of years breaking entirely with the past and raising, after thorough destruction of the past growth, by artificial means a new crop of valuable species.

Large, continuous clearings badly resist reforestation like the prairies, although on a smaller scale. Extensive, even-aged woods form "incubators" for disastrous diseases; suffer from snow, storm, drought, and frost. On the other hand, their management is greatly facilitated, so that reinforcing, cleaning, thinning, regeneration and utilization are much cheapened.

B. Selection of form by the forester.

I. The primeval forms of high forest found by the forester usually appear unretainable. Whatever the case be, the first stroke of the axe is sure to remove the mature and hypermature trees, the preponderance of which belongs to the character of any primeval form.

However, when transforming primeval woods into cultured woods, the forester should endeavor to retain as much as possible the form originally sanctioned by nature. Such retention is the safest way to sylvicultural success. Still, it usually necessitates heavy investments for permanent means of transportation, and where the owner is unwilling to make them, cuttings by compartments or by strips are required, which in turn lead to the adoption of the advance growth type, shelterwood type, or cleared type of n. s. r.

The strip form, as mentioned elsewhere, seems to be particularly well adapted to meet American needs.

II. The culled forms of high forest must be retained by the forester in the compartment, group or selection form first encountered, unless the culling has been particularly light. Improvement cuttings are not apt to change the form of the forest. Where artificial reinforcing is resorted to, the forest will gradually develop even-aged forms. When after heavy culling the average growing stock per acre is badly reduced, then forms allowing of short rotations are indicated, so especially selection forms and standard forms. Frequently in such cases, the high forest is abandoned, and the coppice forest is resorted to.

III. In the cultured forms, the trend of the times favors uneven-aged forms, notably mixed group forms and narrow strip forms, on account of greater safety.

Heavy "thinnings from above" are in vogue, frequently in connection with underplanting (or underseeding by n. s. r.)

Regeneration is effected either by planting compartments, strips and groups, with or without a shelterwood overhead, or by the various types of n. s. r.

Where the deficiency of the growing stock leads to the adoption of short rotations, standard forms, two-storied forms, underplanted forms or coppice-under-standard forms must be resorted to. In the latter case, of course, the high forest form is thrown overboard.

Paragraph LXVII. High Forest by Species.

A. Oaks: The Oaks rarely appear in pure stands.

1. Primeval woods. The primeval high forest exhibits the Oak:

a. As the lower story planted in groups or compartments underneath an upper story of Long-leaf Pine, Loblolly Pine, Short-leaf Pine;

b. In small pure groups sprinkled amongst the Bald Cypress and Red Gum of the southern hummocks;

c. In the selection form grafted upon compartments of high forest of other hardwoods, notably of Chestnut, Hickory, Gum (Ten.); or grafted on compartments of Kalmia, Rhododendron, Chinquapin (N. C.).

d. In pure even-aged groups (prairie borders).

e. In selection forests mixed with many other hardwoods also in selection form.

II. Culled high forests: The culled forest of oak is usually axe-culled as well as fire-culled, thus partly losing its character as a high forest.

The n. s. r. of White Oak, Chestnut Oak and Scarlet Oak at Biltmore proceeds selectionwise or in compartments, notably so on Indian fields in the Pink-beds; underneath Chestnut, Maples, and Oaks on Poplar hill; mixed with Hickory on the lower west slope of Averys creek and so on.

The Oaks endure shade well for a long number of years, trailing on the ground until freed from superstructure. Coccinea three years old is only five inches high, being clipped back continuously by insufficient lignification of its top-shoots.

Even-aged polewoods of Oak are found all over the Blue Ridge and the Piedmont Plateau. Examination will usually prove them to be fire-culled coppice formed by the fire-killed, younger age classes of primeval woods (seedlings, saplings and small poles).

III. Cultured high forests.

The cultured high forest at Biltmore is still *in statu nascendi,* in the plantations on abandoned fields as well as in the n. s. r.'s of comp. 102 (compartment type), the slopes of Ducker Mountain, etc. The growth of the Oaks during early youth is very slow. The soil is usually so badly hardened as to require artificial help to n. s. r. Oak seedlings and saplings are rare in Pisgah Forest (excepting 3-year-old Scarlet Oaks).

The Oaks mingle with the Short-leaf Pine everywhere as an undergrowth started by n. s. r., or as a companion-growth in Pine pole-woods. Here too, however, the fires have usually converted seedlings and saplings into stoolshoots.

In the S. E., regeneration under shelterwood or in advance of logging (by the group type or by the compartment type) seems advisable. In the mixture with the Oaks should be encouraged: Maples, Black Gums, Pines (White Pine grows and retains its branches for a long time in the mixture), Chestnut, Hickory, Walnut.

Record of seed years at Biltmore:

White Oak: good in 1899.

Post Oak: in 1900 the only mast-bearing oak.

Black Oak: splendid, full mast year in 1901 in all situations.

Spanish Oak: splendid, full mast year in 1901.

Chestnut Oak: promises well in 1904.

B. Chestnuts:

1. Primeval forests:

Actually primeval forests of Chestnut seem very rare. The Chestnut woods of the Appalachians have been ransacked by fires for many decades of years. The n. s. r. seems to have been of the selection type. Chestnut seems to avoid limestone-soil and ceases to occur where limestone appears (Ky; Ten.).

II. Culled high forests:

The fire-culled forest shows an absolute lack of seedlings, saplings and poles.

The axe-culled forest consists merely of coppice.

Trees beset with dead branches are invariably wormy (Lymexylon).

Seed years seem to be getting scarce, possibly under the influence of fires, to judge from the reports of mountaineers. The old trees are frequently stagheaded and fail to successfully regenerate their kind.

Seedlings one year old are about eight inches high, when found in the woods. They appear individually scattering and not in groups.

III. Cultured high forests:

The cultured forest usually has the form of coppice or coppice-under-standards. Plantations in the United States are made more for fruit-growing than for timber-growing. The abandoned fields at Biltmore seem too dry for successful development. Chestnuts planted as an undergrowth below Oak and Pine have done poorly, owing to the ravages of squirrels.

The poles and trees seem to badly resent any sudden interference with the leaf canopy and with the humus.

Thinnings and cuttings in the shelterwood system should be light.

The competition of stoolshoots invariably formed after cuttings reduces the prospects of seedlings simultaneously obtained. Stoolshoots cannot be entirely prevented by deadening previous to cutting.

Chestnut produces a splendid humus and is an excellent companion for Oaks, Hickories, Walnut, Black Cherry, Ash and Yellow Poplar; also for White Pine and Hemlock. It regenerates in mixture with Yellow Poplar on small abandoned fields of Pisgah Forest to a limited degree.

Seed years: Fairly good mast in 1898.

On the mountain tops, where Chestnut stands in an orchard-like position, seed occurs annually.

C. Hickories:

I. Primeval forest: The Hickories appear regenerated in the selection type and in the group type.

II. Culled high forest: The Hickories suffer badly from fires. Fires do not kill the poles, but cause the butts to burst subjecting them to decay. Weeding and heavy improvement cuttings are beneficial.

III. Cultured high forest:

From the early pole stage on, the crowns should be placed in a free position so as to cause the formation of wide rings.

At Biltmore, the boles are apt to be very branchy, the tough limbs being very persistent.

In the mountains, on stronger soil, the boles clear themselves readily.

The Hickories regenerate by n. s. r. in abandoned fields in mixture with Black Gum, Sassafras, Yellow Poplar, Locust, Oaks, etc.

In the plantations on abandoned fields at Biltmore, Bitternut alone promises to be successful. The other species are badly handicapped by rodents and seem to be of very slow growth.

The Hickories seem to be immune from damage by frost in their native country; not so in Germany.

Seed years are not of record.

D. Walnuts:

I. Primeval forests:

The Walnuts appear in the primeval woods invariably in mixture with other species, on strong soil, seemingly regenerated by the selection type.

II. Culled high forests:

The Walnuts seem remarkably fireproof from the early pole stage on. Seed regeneration is rare in the woods, but more frequent on old deadenings close to habitations, where the squirrels were held in check.

III. Cultured high forests:

Without artificial help, n. s. r. seems very problematic. Under any circumstances, the rodents must be kept off.

Plantations are frequently found and do very well in early youth, unless the soil is badly hardened and impoverished. The stands should be dense, whether pure or mixed with Oaks etc., so as to produce clean boles. Plantations seem to fail in the close proximity of old trees.

The plantations at Biltmore have failed invariably in the woods, owing to the ravages of squirrels; toungya on leased farms shows poor success, owing to the unreliability of the lessees; plantations of seedlings three years old failed badly; plantations of yearlings freeze to the ground annually on all slopes; plantations of nuts on small fields have done very well, where the ground was good; and the change from good to bad, brought about by the undulations of the soil, is very marked. Failures on poor soil are now doctored up by a nursegrowth of Yellow Pines,—a remedy promising some success.

E. Beech:

I. The primeval forest exhibits the compartment, group and selection type of n. s. r. The humus is usually very heavy and so moist that fires have a poor chance to spread. In the South, at lower altitudes, Beech merely fringes the river banks.

II. The culled high forest shows many stump sprouts, stumps three feet high forming the sprouts on the top of the stump.

In the Blue Grass Region, huge park trees are frequently found in a dense undergrowth of seedlings and saplings. Here the more valuable species have been culled out many years ago, and the Beech is left in exclusive possession of the soil.

III. The cultured high forests of Beech are easily regenerated in the shelterwood-compartment type. The selection type yields branchy boles. Beech is the best companion imaginable for faster-growing species; is splendidly qualified for an underwood planted beneath aristocratic species; is exacting and sensitive.

Plantations on abandoned fields are out of the question, except at high altitudes.

No seed years are of record at Biltmore. The trees on the river banks fruit annually.

F. Basswood:

I. Primeval forests:

In the Lake States and in the Alleghanies, Basswood exhibits the form emanating from the selection type of n. s. r., grafted on the compartment type of White Pine or of Hard Maple, or else mixed with Hard Maple, Elm, Chestnut, Red Oak, Yellow Poplar.

II. Culled high forests:

The regeneration follows the selection type; fires clip the seedlings and saplings; larger poles and trees seem to withstand well.

III. Cultured high forests:

Young seedlings develop very slowly; they are less sensitive than their shade-endurance would indicate. Pure forests are found only in Russia.

Seedlings planted at Biltmore on old fields, of strong qualities, have hesitated to develop for six years, growing bushy and crooked; in 1904, they promise good results.

Linden underplanted below Oaks and Chestnuts after moderate thinning on North slopes seems to answer admirably, forming long and straight, although overhanging topshoots.

Seedyears in Pisgah Forest occur annually. The majority of the seeds, however, seem to drop immature.

G. Yellow Poplar:

I. Primeval forests:

Yellow Poplar appears invariably in the selection type, or in the form of standards.

II. Culled high forests:

The species attempts unceasingly to propagate its kind by n. s. r. The heavier the destruction by the axe, the better are its chances for success. Fires, on the other hand, annihilate the seedlings and check the chances for regeneration thereafter, owing to a rank growth of weeds following the fires. In Pisgah Forest, seedlings and saplings were entirely lacking, until fires were stopped.

The regeneration on old fields, on the other hand, is prolific and easy. Cattle press the seeds into the ground and check the competing weeds. Sassafras, Locust and Pine frequently act as ushers. The old fields are usually protected from fire by the owners wishing to protect their fences.

No known species prunes itself as readily from branches as Yellow Poplar, the dead branches popping off without leaving any stumps.

III. Cultured high forests:

No species at Biltmore is as easily regenerated by n. s. r. as Yellow Poplar. In Biltmore Forest, the group type is readily carried through with the help of three or four mother-trees to the acre. The other companions of the mother-trees, notably Oaks and Chestnuts, are gradually cut away; spreading Dogwoods are deadened to prevent them from forming stoolshoots.

In Pisgah Forest, regeneration is helped by preceding pasturage (especially in early spring, before the seeds of Poplar germinate) and by weeding following in the wake of n. s. r.

The seeds will never sprout in the humus; seedlings born late in spring (June) and showing the cotyledons still in September are sure to be killed by frost; also seedlings growing in the shade of weeds. The logging roads and log yards are real "nurseries" for Poplar. On steep ground, the seedlings are washed out by the rain.

The growth is very fast.

Seed years are annual; hollow trees are likely to furnish very poor seeds.

Plantations of 3-year-olds at Biltmore on poor old fields did badly; on good soil, especially where a volunteer growth of Locust has joined the plants, the success is complete.

H. Maples:

I. Primeval forests:

Here the regeneration follows the compartment type (Adirondacks, Missouri valley), the group type and the selection type (Biltmore, Northern Minnesota). Maple usually appears in mixture with other hardwoods, with Spruce and White Pine. Soft Maple occurs in low, moist sites as well as on dry ridges. Hard Maple demands well-drained and strong soil, preferring Northern aspects.

II. Culled high forests:

After culling, the younger stages of Maple are usually left in possession and develop in dense thickets, preventing more valuable species from establishing themselves. In the Adirondacks, Soft Maple is frequently found on Spruceflats after windfalls (associated with Yellow Birch).

III. Cultured high forests:

Dr. Fernow at Axton succeeded in establishing, in places, a splendid regeneration obtained from advance growth n. s. r. of the compartment type, removing the parents at one stroke. In Europe, the shelterwood compartment type answers admirably.

SYLVICULTURE

Biltmore Forest is deficient in Maple. Still, Hard Maple planted on abandoned fields, pure or in mixture with White Pine, has done admirably, excepting dry S. W. slopes, dry spurs, and very moist river bottoms.

In Pisgah Forest, Red Maple usually appears as a weed overshadowing aristocratic seedlings.

I. Ashes:

I. Primeval forests: The Ashes usually regenerate and stand in patches or groups, occupying the moister sites.

II. Culled high forests:

Protected by moist ground, the Ashes stand a good chance to escape the fires. During early youth, the seedlings endure remarkably heavy shade. Weeding and improvement-cuttings produce splendid results.

III. Cultured high forests:

Regeneration in the group type is easy, if helped by cleaning (Ducker Mountain of Biltmore Estate) and gradual removal of the obstructing trees. On old fields, on moist slopes, White Ash is often accompanied by Yellow Poplar and Halesia.

Plantations of 3-year-old Green Ash have failed utterly at Biltmore on dry, hard soil.

Plantations of 3-year-old White Ash in half-swamps do very well; also seed plantations on good soil in the gaps of a ridge.

The early growth is very fast.

Seeds are profusely produced from the pole stage on.

J. Red Spruce:

I. Primeval forests: The primeval Spruce woods appear as more or less even-aged compartments in the swamps and sloughs of the Lake States and on the dry, shallow South slopes of New England; in the cleared group form and in the selection form in Western N. C. at altitudes exceeding 5,000 feet, mixed with Abies fraseri (selection); in the selection form, grafted upon compartments of Beech and Maple, on the hardwood slopes of the Adirondacks. In the latter case, Spruce never regenerates in the heavy layer of broad-leafed humus, but selects invariably the half-rotted corpse of a dead tree for a seed-bed.

II. Culled high forests: In slightly culled forests immune from fires, Red Spruce seems to reproduce with remarkable ease. On fired ground, Birches and Cottonwoods frequently act as ushers. Its persistence below an impenetrable leaf canopy of Beech or Maple is surprising. Freed from superstructure, after long years of suffering, it answers the chance for rapid growth almost immediately.

III. Cultured high forests: Spruce requires high atmospheric moisture; is satisfied with shallow soil; can be readily reproduced by n. s. r. as well as by planting.

Seed years: Prolific in North Carolina in fall 1901. The trees, top heavy with cones, were mowed down by storms.

K. White Pine:

I. Primeval forests: The White Pine of the primeval woods appears in compartments, almost even-aged, or in groups, either pure, or with an admixture of Hard Maple, Linden, Elm, Yellow Birch; or in the form of standards over Red Spruce and Balsam; or in the selection form, as in the Calmia thickets of the Pink-bed Swamps. It is flat-rooted, subject to windfalls, in the North not tolerant of shade.

II. Culled high forests: The gorgeous White Pine forests of the Lake States, after culling followed by fires, are invariably surrendered to a shrubbage of hardwoods. Second growth is found in beautiful groups underneath Norway Pine; individually sprinkled amongst Jack Pine, Basswood, Birch, etc.; also on old burns in extensive, even-aged compartments; along roads and at the edge of clearings; in New England on old fields.

In Western N. C., White Pine regenerates readily on broomsedge fields; in mixture with the Oaks on the uplands; in mixture with Red Maple and Red Birch in the river swamps, etc.

III. Cultured high forests: At Biltmore, the n. s. r. of White Pine started by a few seed trees succeeds easily in the group type. White Pines planted under dense shelter require freeing soon (compartment 45). Individual trees are very retentive of branches. Plantations on several hundred acres have done admirably. White Pine is the easiest Pine to plant on old fields or in groups in the woods after clearing.

Seed years are frequent at Biltmore, recurring at intervals of two or three years, f. i., fall of 1902 and 1904.

L. Yellow Pines:

I. Primeval forests: The pure group form (Black-hills) or the group form wedded with the compartment form of Oaks reaching a lesser height than the Pines seem to be typical. Pine standards are often left. The compartment form of P. taeda is also frequent. P. divaricata and murrayana invariably occur in even-aged compartments; P. palustris and P. heterophylla usually occur in groups.

II. Culled high forests:

The culled forest is usually visited by fires which gradually convert an undergrowth of hardwoods, where it exists, into coppice. Beneath Longleaf Pine, this undergrowth begins to sprout only when the mature Pine is removed.

P. rigida and P. echinata less than 6 inches in diameter are also coppiced (New Jersey Pines) to a limited extent.

Where the pure high forest continues, fire has usually improved the chances for n. s. r. by preparing a ready seed bed and by lessening the severity of future fires.

All Yellow Pines regenerate prolifically on abandoned fields, often in stands which artificial planting could not produce equally well.

III. Cultured high forests:

The n. s. r. of P. echinata in the Biltmore woods creates nuclei for small groups which are freed and gradually enlarged. Heavy thinnings from the early thicket stage on prevent crowding in the pole stage and hereby check the chances for successful attacks by the bark beetles. Pruning 100 decidedly predestined trees per acre seems remunerative (dead branches only) at Biltmore.

Standard form of P. echinata seems indicated at Biltmore.

All Yellow Pines are easily planted when one or two years old and get along without cultivation on old fields. Heavy growth of weeds, on good soil, however, is sure to smother them.

In pure and large natural regenerations, it is wise to leave some hardwood standards with a view to securing an admixture of hardwood seedlings in due course of time.

In mixture with White Pine, Yellow Pine is soon subdued on good soil, while it retains the lead on poor soil.

Seed years of Pinus echinata at Biltmore occur every seven years. The fall of 1902 was a prolific breeder of seeds even in polewoods 35 years old (Walker-nursery at Biltmore).

CHAPTER III.

THE COPPICE FOREST.

Paragraph LXVIII. Genesis of the coppice forest and its methods.

The coppice forest is either the result of stump-shoots or is obtained from rootsuckers, layers and cuttings.

A. Stumpshoots (or stoolshoots or coppice shoots).

I. Species: All hardwoods whilst young form stump shoots when cut just above the callus. Amongst the softwoods, the Sequoias exhibit enormous stump sprouts. Amongst the Yellow Pines, P. rigida and echinata, after F. E. Olmsted also P. taeda, are capable of developing sprouts from stumps measuring less than six inches in diameter. White Pines, Spruces, Firs, Larches, Hemlocks, etc., never form coppice shoots.

II. Diameter: The sprouting capacity rapidly decreases, usually, with increasing diameter of the stump. The diameter at which the principal height growth is completed usually denotes the limit permissible for coppice rotations. This rule is particularly well illustrated by the behavior of Yellow Pine, Birch, Maple, Yellow Poplar, Oaks, Hickories, etc. Chestnut and Sequoia do not seem to follow the rule.

III. Soil: Good soil allows big stumps otherwise unproductive of sprouts to form stool shoots.

Good soil produces stronger, but less sprouts than poor soil.

IV. Life of stumps: The life and, hence the sprouting capacity of stumps repeatedly coppiced is closely connected with the resistance offered by the timber to decay. White Oak, Chestnut, Sequoia and Locust are perseverant sprouters, the scars on the stump being protected from rotting by the antiseptic qualities of the substances incrustating the heart wood.

The reproductive power of Birch, Beech, and Maple is not sustained for a long time. Ash and Basswood show greater perseverance.

It might be said that a long-lifed species is also a perseverant sprouter.

The sprouting capacity is especially good in species capable of forming a separate and detached root system for the sprout independent from the mother stump. This is the case in species forming sprouts from the base of the stump (at the root collar).

V. Optimum number of stumps per acre:

The optimum depends on the length of the rotation. It is considered to be: For German Oak coppice, rotation 20 years, 2,000 stumps per acre; for Osier culture, rotation one or two years, 80,000 stumps per acre.

VI. Manner of coppicing: The use of the axe is preferable to that of the saw. Stumps should be as low as possible, to begin with. In case of stumps—notably Beech and Birch—coppiced a number of times it is better to cut in the new wood. The scar should allow the water to run off, instead of collecting it like a saucer. The expense of the genesis of the coppice forest is practically nil.

VII. Season of coppicing:

If the wood must be peeled, the cut should be made in early spring. Late spring cutting subjects the new sprouts to early frosts. Coppicing in August is supposed—for similar reasons—to affect the vitality of the stumps. Where the shoots are not to be peeled, cutting in late winter is best. Winter cutting prevents the stumps from bleeding and allows to remove the product cut before the appearance of new shoots without injuring the stumps.

Cutting in fall subjects the stumps to frost-cracks and to bark-blistering; it causes the new fleshy shoots to appear early in spring, at the season of prevailing late frosts.

Accessibility of the locality at the proposed season of cutting and availability of local labor further determine the season of cutting.

VIII. Reinforcing: Where the number of stumps is or becomes deficient, there the owner may plant seedlings or stump-plants to replenish the growing stock.

B. Root suckers: Cottonwood, Willow, Locust, Alder, some Elms and Maples, after European experience even Liriodendron (?) form root suckers, especially on porous soil. The suckers are increased by locally uncovering the surface roots. They might be severed from the stem and planted when two or three years old; but this is expensive. Gardeners often use pieces of roots, say ten inches long and finger-thick, for propagating broad-leaf species in good soil. An observer in F. and T., May, 1904, claims to have found that Fir and Spruce in the Presidential Range of the White Mountains propagate their kind by the natural and unaided formation of suckers developing from long, horizontal roots.

C. Layers: A low, long branch of a standing tree is partly buried in a trench one-half foot deep, held in place by hooks, pins or stones, the end of the branch protruding above ground. The branch thus imbedded forms roots and shoots. The latter are severed from each other a year or two before planting in the open.

Layering is a gardener's method only locally used in parks. At very high altitudes, under the influence of very great atmospheric moisture, the low Spruce branches naturally form roots and shoots in a similar manner.

D. Cuttings: Willows and Poplars are usually propagated by "cuttings," viz.: pieces of branches one foot long and two years old, tipped with a piece one year old. The cuttings are inserted obliquely, the tips barely showing above ground. Planting dagger or turning plow are the tools used. Care must be taken to prevent the bark from peeling off. It is claimed that the constant use of cuttings causes a deterioration of growth. Cuttings of sapling size taken from strong and long branches are also planted in good nursery soil for a number of years and planted in the open ground after catching root. Willows and Poplars allow of heavy trimming. Among conifers, only Sequoia permits the use of cuttings. It is claimed that Sequoia-chips sprout successfully in the moist climate of the Coast Range.

Paragraph LXIX. Pedagogy of the coppice forest.

The coppice forest is tended by cleaning, weeding, and thinning; also by improvement cuttings and pruning.

A. Cleanings: To prevent undesirable shoots from developing, the stumps producing them must be removed. Stumps of undesirable species (Blackgum, Hazel, Alder) can be removed only by digging, or by heaping dirt upon them, or by firing heaps of debris placed on the stumps. Usually, it is preferable to deaden undesirable trees instead of trying to prevent their stumps from forming sprouts. In some species, stumps three feet high will form poor sprouts, a quality which might be taken advantage of.

B. Weeding: Misshapen trees or poles of a desirable hardwood species, cut level with the ground, will at once produce shoots of good quality. Poles badly damaged by fires should be cut for an increase of vitality. Trees left because worthless should be deadened, unless they belong to the aristocracy, or unless they improve the good sprouts as well as the soil in the role of subordinate companions.

C. Thinnings: Thinnings in European coppice woods are rare; in tanbark coppice they usually purport to improve the quality of the bark. Where made, the thinnings usually remove the weaker shoots of a stump for the benefit of the better and stronger shoots. The rotations of European coppice being short, heavy thinnings tend to deteriorate the quality (branchiness and shape) of the shoots as well as of the soil; and light thinnings are rarely remunerative.

In America, coppice of Catalpa, of Chestnut, of Locust and Hickory may invite heavy thinnings where fence posts, telephone posts, railroad ties, wagonstock, etc., find a ready market.

In case of Hickory, thinnings periodically removing the best trees (à la Borggreve) might seem indicated.

D. Improvement cuttings: Improvement cuttings are necessary in culled coppice forest emerging directly from primeval hardwood forest heavily cut or heavily fired. Such forest is invariably encumbered with bushy and worthless standards (if the standards have a value, the forest belongs to the form of coppice under standards described in Par. LXXIII-Par. LXXVIII) interfering with the development of the shoots; or with undesirable species left by the logger. The mob frequently prevails over the aristocrats.

The first final cut at the end of the first coppice rotation usually answers the purpose of an improvement cutting.

E. Pruning: Pruning is required to prevent coppice of Catalpa, Locust and Ash from forming forks or heavy branches. Naturally, pruning is expensive and dangerous at the same time since live branches are removed. The danger is particularly great where the rotations are long, the pruned stump shoots being left for decades of years after pruning.

In the pollarding form, pruning or rather lopping obviously comprises the harvest of the crop.

Paragraph LXX. Key to the forms of coppice forest.

Although coppicing is called a type of natural regeneration, it is an absolutely unnatural measure never adopted by primeval nature. Primeval forms of coppice forest proper do not exist.

Species propagating their kind, at least partially, by rootsuckers frequently form rootsucker forests closely resembling coppice forests proper.

Chestnuts, Locusts and many other hardwoods broken down by storm may form natural sprouts as well from the stumps. Still, these cases are probably so scattering as not to deserve the name of "form of primeval coppice forest."

Thus there remain only two large groups of coppice forests, namely "Culled Coppice Forests" and "Cultured Coppice Forests." In both cases we have to deal only with the large-area form or compartment form of coppice.

Woods seemingly consisting of uneven-aged coppice shoots, mixed in groups or individually, are dealt with as "Forms of coppice-under-standards" (Par. LXXIII-Par. LXXVIII), unless the standards are worthless and promise to remain worthless.

A. Culled forms of coppice:

These forms emerge either directly from omnivendible primeval forms, or else have passed through the intermediate stage of "culled coppice under standards."

I. Characteristic for culled coppice is:

An even display of growth.

A surprising density of stand.

The presence of some weathered and worthless snags and stumps protruding from the even sea of coppice.

II. Subdivisions of culled coppice:

Uniformity being characteristic for culled coppice, sub-forms can scarcely be singled out, unless the means of coppicing—fire or axe—serve as a criterion. Hence there might be distinguished

a. The form of fire—culled coppice, and

b. The form of axe—culled coppice.

This distinction is not made on the basis of different display; but on the basis of difference in treatment required by the two forms.

III. Treatment of culled coppice:

The culled coppice is regenerated by being coppiced anew. In the case of fire-culled coppice, it is wise to delay the second cut as little as possible.

Coppicing in patches or small groups is not advisable, the young shoots requiring all the light available for rapid lignification.

An insufficient number of stumps may call for artificial reinforcing.

Improvement cuttings convert poor coppice shoots interfering with their neighbors from above into healthy coppice shoots pressing their neighbors helpfully from below.

B. Cultured forms of coppice:

No form of cultured forest can be obtained more easily and more cheaply than the form of cultured coppice.

In the European hardwood forests, the cultured coppice of the past has often served as the forerunner of the cultured high forest of the present sylvan era.

I. Characteristic for cultured coppice is an even stand, a dense stand, freedom from undesirable competitors and tree weeds.

II. Subdivisions of cultured coppice forms are:

a. The simple form of cultured coppice, where all shoots have the same age.

b. The two-storied form of cultured coppice, where the growing stock displays two tiers of leaf canopy, viz.: an upper and a lower tier, the age of the tiers differing by the length of a rotation.

In addition, a form of "high stumps" is usually distinguished, where trees are cut some six to ten feet above ground and where the shoots forming on that high stump are cut at short intervals. This form, adapted particularly for the production of fascines at levees, is known as:

c. The pollarding form of cultured coppice.

In this form, rotations of one to five years are usually adopted, and the "lopping" takes place in the "new wood."

III. Treatment of cultured coppice forms:

Regeneration in the cultured forms of coppice is, of course, by coppicing, helped by planting stumps, cuttings, suckers and layering. Regeneration may proceed against the direction of the wind which brings the heavy frosts of spring and fall (blizzard-direction). Cleaning and thinning are often indicated.

Paragraph LXXI. Critical remarks on coppice forests.

The coppice forest generally furnishes small-sized timber, notably firewood and farm supplies, but no or little saw timber. Its production is not so many-sided as that of the high forest, and for that reason not equally safe.

On the other hand, allowing of shorter rotations, the timber investment is much smaller than in high forest, and the returns from "final yields" are more frequent.

A comparatively small area may produce, under a coppice form, a regularly sustained yield.

The soil of the forest is frequently exposed, and shows a thin layer of humus. Shallow soil is, however, sufficient for the welfare of a coppice forest.

The water-retaining capacity of the coppice forest is small.

Coppice forest is less exposed to storm, fire, snow, and insects (being broad-leafed usually), and more exposed to late and early frosts than high forest. As a stock pasture, it is much more productive than high forest; but also much more damaged by pasture.

The expense of regeneration and of pedagogy is slight. The species forming shoots from below the ground and those forming root-suckers usually allow of long rotations.

Paragraph LXXII. Coppice forests by species.

A. Oaks:

I. Culled Oak coppice:

Culled Oak coppice is usually fire-culled. The stumps do not tire of emitting shoots after each fire. Still, the shoots become weak, stunted and bushy-crowned and refuse to grow in diameter as well as in height.

It is remarkable to find that these worthless shoots may be replaced by strong shoots after coppicing with the axe.

The poorer the fire-culled Oak coppice, the greater is the improvement obtainable by axe-coppicing.

II. Cultured Oak Coppice:

In Europe, Oak coppice is the form in which Oak bark is raised for tanning purposes, under a rotation of fifteen to twenty-five years.

In America, coppiced Oak is used only for charcoal and firewood—rarely for railroad ties. Rotations yielding ties will not allow of ready reproduction under the coppice form, unless the soil is very strong.

At Biltmore, Post Oak three inches through, White Oak ten inches through, Black Oak and Scarlet Oak twelve inches through are unlikely to sprout.

A rotation of not to exceed forty years seems indicated. Such a rotation might also yield hoop poles, poles for splitwood fabrics and minor wagonstock.

B. Beech:

Beech coppice yields firewood only, charcoal and so-called retort-wood for dry distillation.

The sprouting capacity of the Beech invites short rotations. Strong soil is required.

C. Hickory:

Hickory coppice promises good financial results on strong soil only. Fires must be strictly kept in check, owing to the heavy scars which they inflict on Hickory. Rotations of about twenty years, low stumps and winter cutting seem required.

On Biltmore soil, stumps over six inches in diameter usually refuse to sprout.

D. Locust:

Locust coppice densely planted on old fields seems to be a good investment, although the poles thus produced consist of sappy wood undesirable for fence posts. The young shoots suffer from a pith-boring moth (Ecdytolopha species).

The sprouting capacity is very good, helped by the ready formation of rootsuckers.

In Germany, wagon stock is obtained in rotations of twenty years.

E. Chestnut:

Chestnut is the American species best adapted for the coppice forest. Stumps of any diameter emit sprouts. A rotation of twenty to forty years will yield vineyard stakes, hop poles, telephone poles, posts, rails, ties and wood for the extraction of tannic acid; a rotation of five years is said to be used for the production of hoop poles for barrel hoops.

The European complaint does not seem warranted in America that rotations exceeding twenty years invite a disease known as "heart-rot."

In Alsace-Lorraine, thinnings take place in the tenth year; the cut is made in early winter, and the stumps are sometimes protected from the influence of frost by heaps of brush. In the Appalachians, such precautions are not called for. It is unnecessary, if not unwise, to reduce the number of sprouts starting from one stump artificially. Spring cutting and high stumps are objectionable.

On dry and impoverished soil, or under the regime of fires, Chestnut coppice is hopelessly lost.

F. Cottonwood:

Coppice forest of Cottonwood produces match stock and pulpwood. The stumps have little vitality and will not endure more than four rotations of twenty years each. Very low stumps are required to insure healthy sprouts and to encourage the production of root-suckers. The growth is very fast in the first years.

G. Willows (Osier-culture):

Osier culture is considered a money maker in Germany where labor is cheap. It is now in vogue in New York and in New Jersey. The best species are Salix viminalis, Salix amygdalina, Salix purpurea, Salix acutifolia (caspica). The rotation comprises one or two years. With the exception of Salix caspica, a moist soil is required (meadow land in river bottoms) by the willows.

The stumps do not yield a return for more than twelve to sixteen years.

For the formation of an Osier grove, shoots two feet long are used of which about 80,000 are put in per acre. It is stated that the more shoots there are per acre, the better is the quality of the Willow, as branchy stuff cannot be used for basket making.

Cultivation between the rows is said to be very advisable or even necessary, especially in the first years. There are many insects feeding on the leaves and many fungi besetting the leaves of the Willows.

A one-year rotation is best. After three or four years, however, a two-years' rotation frequently intervenes, so as to allow the root to develop unhampered. The shoots two years old are used for the framework of heavy baskets. The cutting takes place in July and August. Krahe, however, advises cutting in November.

The first cost of an Osier plantation is very high. After Krahe, the net yield amounts to $32 per acre per annum.

CHAPTER IV.

THE COPPICE-UNDER-STANDARDS FOREST.

Paragraph LXXIII. Genesis of coppice-under-standards forests and its methods.

"Coppice under standards" consists of an underwood and of an overwood.

The underwood is nothing but simple, even-aged coppice.

The overwood exhibits the selection, sometimes the group form of high forest, and is supposed to recruit itself from seedlings.

A. The underwood:

I. Species: The species forming the underwood must combine natural sprouting capacity with shade endurance. On good soil, a smaller amount of both qualities is required. Excellent species for underwood are Basswood; Chestnut; Gum; Hornbeam; Calmia and

Rhododendron; on strong soil, Ash and Hickory; underneath a light overwood also Oak.

II. Purpose: The underwood supplies or may supply

a. Companions for the younger age-classes of the overwood, causing them to form clear boles;

b. Protection of the soil, enriching it by its humus;

c. Firewood and small timber; also tanning material.

The underwood yields a direct revenue only in case "c." Obviously, where there is no market for firewood or small timber, the underwood is only indirectly useful.

III. Formation: For diameter, vitality and number of stumps, also for manner and season of cutting, the remarks of Par. LXVIII. A. (about coppicing) hold good.

B. The overwood:

I. Species: The species forming the overwood should be storm-firm and small crowned. Light demanders are usually preferred.

Yellow Pines produce wide-ringed timber on strong soil and suffer from sleet. Good species are: White Oaks, Red Oak, Hickory, Walnut, Yellow Poplar, Black Cherry, Locust, Larch, etc.; on poorer soil Yellow Pines and Long-leaf Pine (over Black Jack).

II. Age-classes: The number of age-classes in a normal overwood equals the fraction $\frac{R}{r}$ wherein

R represents the length of the rotation in the overwood, and

r represents the length of the rotation in the underwood.

The normal difference of age between consecutive classes is "r" years.

III. Normal formation: The overwood is composed of "standards" regenerated, at the year of coppiced underwood, from self-sown seed falling from the overwood or, in the cultured forest, from planted seedlings. The seedlings of the overwood grow up immerged and often badly endangered in the new underwood. When this is coppiced at the age of r years, an improvement cutting takes place simultaneously removing misshapen or damaged standards of the various older classes as well as the weaklings in the youngest class. By this improvement cutting the leaf canopy of the standards, which has had ample chance of enlargement during the past r years, is cut back to a normal limit.

The older an age-class is, the smaller is the number of its constituents.

C. Abnormal formation of overwood and underwood:

A normally proportioned and normally formed overwood is never found. Deficiencies lie

1. In a lack of one or the other age-class;

2. In an abnormal number of constituents per class;

3. In the fact, that the overwood is partially recruited from stoolshoots and not from seedlings.

Abnormal coppice over-standards is the usual consequence of the culling of primeval hardwoods or of primeval pineries forming a superstructure over Oaks, Hickories, Gums, etc.

The burned slopes and outskirts of the Alleghanies usually belong to the coppice-under-standard form. The fire-coppiced underwood here consists of Soft Maple, Calmia, Rhododendron, Chestnut, Oaks, Hickories, Black Gum, Sourwood, Halesia, etc., etc., all of which are usually devoid of value.

Culled and fired forest of Pinus echinata, taeda and palustris frequently belong to the same form, with Oaks in the underwood and the Pines in the overwood.

Paragraph LXXIV. Pedagogy of coppice-under-standards forest.

Coppice under standards is or may be tended by cleaning, weeding, improvement cuttings, pruning and thinning.

Thinnings are applied to the underwood only; whilst the overwood alone is the object of pruning.

A. Cleaning purports to eliminate undesirable shoots in young coppice, or removes desirable shoots liable to interfere with the development of overwood seedlings imbedded in the coppice.

B. Weeding removes weed trees, usually tending to form new sprouts from the stumps of the weed trees removed. Weeding is a necessity where a culled forest is to be converted into a cultured forest, the culled forest containing a large number of weed trees.

At Biltmore, the weed trees removed are Black Gum overshadowing the coppice and the Pine seedlings standing therein; fire-scalded Oaks or Hickories, bent and low crowned; wolfs of Yellow Pine; pretentious Dogwoods or Halesias and so on.

C. Improvement cuttings improve the prospects of the overwood, remove undesirable members of the overwood and regulate the number of the constituents forming an age-class of the overwood. "The normal cuttings in the overwood are improvement cuttings."

In semi-normal woods, the oldest class of the overwood is entirely removed. Class II is reduced to the former membership of Class I; Class III is reduced to the former membership of Class II, etc. It stands to reason, that the least desirable members of a class should be thus removed. In semi-normal woods, the improvement cuttings take place at the time at which the underwood is ripe for coppicing.

The improvement cutting yields timber of all sorts and of all sizes obtained from the various age-classes.

The improvement cutting does not regularly intend to help regeneration. Frequently, of course, the stumps of trees removed by the improvement cutting form sprouts partaking in the coppice-tier.

D. Pruning: Dead branches of the overwood trees might be removed to develop timber clear of dead knots.

Live branches of overwood trees formed low on the bole are removed to lessen the intensity of the shade to which the underwood and the seedlings imbedded therein are locally subjected.

The members of the overwood, owing to their free position, are apt to form and to retain heavy branches. The act of pruning in coppice under-standards corresponds with that described in section sixty-three for high forest.

The coppice is pruned only in rare instances, f. i., for the improvement of oak tanbark.

E. Thinnings are sometimes indicated in dense coppice in order to increase the food and light supply of the youngest age-class of overwood imbedded in the coppice; or in order to increase gradually the air space surrounding the members of that class, so as not to subject them to the shock of sudden exposure at the time of coppicing: or to obtain the ends of Par. LXII. A., especially where the overwood classes appear in groups; or to improve the quality and the quantity of the bark in tanbark coppice.

In all cases, the thinning must yield a surplus revenue.

Paragraph LXXV. Key to the forms of coppice-under-standards forests.

The primeval woods do not contain any form of coppice under standards. In culled hardwood forests, on the other hand, these forms are almost regularly met with.

A. Culled forms of coppice under standards.

I. Characteristics: Primeval hardwood forests are usually paucivendible only. After lumbering the merchantable species and sizes, a rank growth of coppice shoots frequently enters an appearance under the assistance of fires, overshadowed by poles and trees of all age-classes devoid of present value. Many individuals of the overwood are badly burned; or are hollow, fungus decayed, worm riddled, etc.

Thus whilst the underwood consists of fire coppice or shoots sprouting from the stumps of merchantable trees, the overwood consists of undesirable species and of immature trees usually crippled by firing and felling. In addition, there are plenty of weed trees left on the ground. The younger age-classes of the overwood are usually absent.

In forests originally composed of a Pine overwood and of a hardwood underwood—a form once frequently found all over the Southeast—the lumberman usually removes merely the taller Pines scaling over ten inches in diameter. The smaller Pines, if fireproof, henceforth join with the hardwood trees and hardwood poles in the formation of an overwood. The underwood consisting of miserable fire sprouts is continuously clipped by forest fires. The butts of these "snags" are flattened on the ground, as if liquid wood had hardened on it. The shoots, weakly inserted on the callus, can be torn off easily.

If these snags are cut, fresh shoots will form, of much greater vigor and of greater strength at the point of insertion.

II. Subdivisions of culled coppice under standards:

The number of forms of coppice under standards is particularly great, owing to the variations occurring in the tiers of forest, viz.: the overwood and the underwood.

a. The overwood is omni, multi, or pauci vendible, as the case may be. It is arranged either in groups or in patcnes (individuals) imbedded in the coppice. Thus we obtain:

1. The form of culled coppice under standards raised in the group type, and

2. The form of culled coppice under standards raised in the selection type.

b. The leaf canopy of the standards covers a certain percentage of the ground. This percentage, where high, forces the underwood into a minor role; where small, it allots to the underwood the major part.

The Longleaf Pine woods of the South, after heavy culling, illustrate the latter form; the Shortleaf Pine woods of the Biltmore Plateau exhibit the former form. These forms might be designated as:

1. The form of prevailing coppice under standards;

2. The form of coppice under prevailing standards.

c. According to the means of coppicing, there should be distinguished

1. The form of fire-culled coppice under standards;

2. The form of axe-culled coppice under standards.

III. Treatment of culled forms of coppice under standards.

Improvement cuttings and, where improvement cuttings cannot be made, weeding are usually required.

Fire coppice should be cut down, wherever the growth is stagnant.

An undue preponderance of standards may be checked by the use of the axe.

Planting of seedlings can usually be dispensed with. Where it is advisable to plant seedlings, the coppice must be cut clean to begin with.

B. Cultured forms of coppice under standards:

I. Characteristic for the cultured forms of coppice under standards is the lack of weed trees and of unhealthy standards; further the geometric regularity of the figures considered as compartments and sub-compartments.

The overwood is composed only of storm-firm and light-demanding species.

II. Subdivisions of cultured forms of coppice under standards.

As in the culled forest, there should be distinguished:

a. The form of cultured coppice under standards raised in the group type with

1. Prevailing coppice, or with
2. Prevailing standards.

b. The form of cultured coppice under standards raised in the selection type with

1. Prevailing coppice, or with
2. Prevailing standards.

The standards might be planted in regular rows (Charles Heyer's idea) or in regular groups or—irregularly—in suitable places; or they might be recruited from self-sown seed under the selection type.

III. Treatment of cultured forms of coppice under standards.

The regeneration of the overwood as well as its pedagogy is difficult, unless the group type is carried through. Individual seedlings are very apt to be suffocated in the mass of faster-growing coppice and require continuous, careful attention. Thinnings are required to prepare the youngest class of standards immerged in the coppice for its future task.

The overwood is sometimes pruned—in this case of dead as well as of live branches.

Paragraph LXXVI. Critical remarks on coppice-under-standards forest.

The coppice-under-standards forest combines the good qualities of the high forest with those of the coppice forest. It furnishes timber of all sizes in the largest possible variety. It requires a moderate investment sunk into the growing stock and allows the overwood to grow into log size at a very fast rate. It is a good form for the owners of small woodlands desiring steady returns. It protects the fertility of the soil better than the coppice form.

The logs furnished by the overwood raised selectionwise are necessarily branchy and wide ringed, with the incident bad and good qualities of such logs. The trees usually do not yield more than two saw logs.

Where the underwood is unsalable or low priced, stress must be laid on a prevalence of the overwood. Where it is valuable as a tanning material or as wagon stock, the underwood is favored.

The danger from fire—since hardwoods are usually at stake—is not very great. The density of the brushy underwood, however, aggravates the difficulties confronting the fire fighter.

In Europe, "coppice-under-standards" is more and more abandoned and restricted to the inundation districts along the rivers. Here, on strong soil, the undergrowth endures an enormous amount of shade, and the overwood develops fairly long boles in spite of a free position.

The coppice-under-standards form in Europe requires careful, minute and honest management: careful, because the leaf canopy of the overwood rapidly increases during the rotation of the underwood; minute, because individual trees or groups of trees must be continuously watched; honest, because an unscrupulous forester or a thoughtless owner may easily and heavily reduce the capital of the forest whilst claiming to merely withdraw revenue produced by it.

In America, in the hardwood forests of the Alleghanies and in the pineries of the South, the form is destined to play a most important role. The form exists and will have to be retained for decades of years to come, owing to its tempting financial merits; the ease and cheapness of regeneration; the short period of waiting between remunerative cuts; the variety of produce; the fast rate of growth; the small amount of growing stock required for "sustained" yields and so on.

In the course of time, curtailing the cut of standards or allowing the coppice to grow into larger sizes, the forester may gradually convert the coppice-under-standards forest into a high forest. The average growing stock, per acre, in the high forest contains about twice as many cords of wood as the average growing stock in the coppice under-standards forest.

On the other hand, by removing all standards, the form of simple coppice is readily obtained.

In the Oak-coppice-under-Pine-standard forest of Biltmore it has been observed that the Pine poles suffer less from bark beetles than they do in the denser polewoods of the high forest of Pine.

Paragraph LXXVII. Coppice-under-standards by species.

By culling and firing, every primeval forest of hardwoods existing in the United States is converted into coppice under standards. Again, many, nay, almost all two-storied high forests in the South having Pine in the overwood and hardwood in the underwood present the form of coppice-under-standards in a modified manner.

The number of constellations of species for a place in the overwood and in the underwood is endless.

A few remarks on characteristic forms must suffice.

A. Chestnut-coppice under standards of Yellow Poplar, White, Chestnut and Red Oak, Hickory, Ash, Locust,—the Pisgah Forest form.

Certain age-classes of the standards—the sapling stage and the pole stage, are invariably absent, owing to the fires of the last decades. The number of Chestnut stumps is deficient. The weed species of the forest (Halesia, Soft Maple, Dogwood, Calmia, etc.) readily replenish the coppice-stratum. The standards regenerate their kind readily where the weeds are not too rank. No means are known by which to extirpate the tree and bush weeds preventing n. s. r. of the standards in a sufficiently promising way. Heavy pasturage in early spring practiced before the Chestnut stumps had time to sprout and before the seeds of the standards (excepting Chestnut Oak and White Oak) had time for germination may solve the problem. Such pasturage, whilst it checks the weeds, presses the seeds of the standards at the same time into the mineral soil. Other remedies are: Deadening; cutting with high stumps left; bark peeling; removing side branches with a brush axe, etc. However, entire extirpation of the ligneous weeds does not seem financially advisable at the present time. Frequently it might be best to leave the weeds untouched for the time being, postponing the battle until the undergrowth of seedlings and coppice shoots requires increased influx of light. Then, too, the cutting of the weeds will force them to be satisfied with a subsistence below the level of the underwood.

Chestnut standards should not be left, since the shock of a sudden change of surroundings causes them to sicken. The adjoining woods will tend to reinforce the regeneration area by n. s. r. of Chestnut, where the compartments simultaneously coppiced are small or narrow. Artificial reinforcing seems unnecessary although the planting of Walnuts in suitable places may prove remunerative.

B. Oak coppice mixed with Hickory coppice under Pine standards.

This form prevails on the Biltmore Plateau and over vast areas in Arkansas, Mississippi, Alabama, North Carolina, South Carolina, etc.

Silvicultural treatment is possible only where the Oak can be removed to a nearby fuel-market.

Rotations of thirty to forty years for the coppice seem best.

Shorter rotations are required where the coppice is badly damaged by fires.

In seed years of Yellow Pine, the coppiced area should be as large as compatible with the market. It might be wise to cut early in fall and to burn the coppice before the Pine seeds begin to fall. Seed years of Pine at Biltmore occur at intervals of seven years. Improvement cuttings should make up the sustained yield, as far as possible, in years of deficient seeding; or such compartments should be taken in hand, in which the coppice growth is richly beset with Pine poles and Pine saplings.

In the course of the improvement cuttings, the nuclei of n. s. r. of Pine require careful attention. Weeds like Chinquapin and Black gum are checked wherever they obstruct the underwood; where they form part of the underwood, especially under groups of Pine, they should be thankfully accepted as shade-bearing improvers of the soil.

White Pine is not adapted to the formation of standards. During the earlier stages, it retains its branches badly where isolated in Oak coppice. During the later pole stage, it is apt to suffer from windfall. Groups of White Pine standards will answer better than standards individually scattered.

CHAPTER V.

PROPAGATION OF FOREST PRODUCTS OTHER THAN WOOD AND TIMBER.

Paragraph LXXVIII. Raising of forest by-products.

In many cases better revenue is obtained from the by-products raised in the forest, than from the wood and timber. In backwood sections, closed to traffic, forest pasture often yields the only means of obtaining revenue. In densely wooded districts, the combination of agriculture with tree growth is often advisable. The main products thus obtained and the industries connected with their production are:

A. Tanbark and raising of tanbark:

The thickness of the bark used for tanning purposes and obtained either under a high forest or under a coppice forest system is increased by proper thinnings. In Oak bark coppice abroad the number of stumps per acre is about 2,000, reinforced by stump planting at each cutting. The healthier the growth of the shoots, the better are the tanning contents of the product.

In America, at the present time, no difference is made in the price of old, corky bark and of young, fleshy bark obtained from shoots only five inches in diameter.

B. Cork industry:

The cork industry is conducted in Southern France, Spain, Portugal and Northern Africa. For America, its introduction seems highly remunerative.

Experiments made in Georgia and in the Carolinas with plantations of Cork Oak have produced very healthy trees; for reasons unknown, however, the cork production was deficient. Possibly the wrong species or the wrong variety was selected, or else mistakes were made in choosing soil, exposure and silvicultural treatment.

Mayr recommends experiments with Quercus variabilis for the section of Germany productive of Castanea vesca.

C. Forest pasture:

Up to 1880, forest pasture in Long-leaf Pine woods of the South (Cane-brakes) and in the hardwood forests of the Alleghanies has occupied the rank of the most important forest industry. Nowadays, pasture is indicated on many a windswept ridge where the growth of timber is stunted, whilst the atmospheric moisture allows of a luxurious production of grass. Under nut-bearing trees, hog pasture is highly remunerative. In "strong" coves, the growth of weeds offers splendid forage for cattle.

The more inaccessible the forest, the less is the value of the tree growth. Here an industry is advisable which converts vegetable fibre into animal matter. At the same time, the advantage gained by pasturage during and previous to regeneration frequently reduces the expense of regeneration.

Whether the fencing of forest pastures is advisable depends on circumstances. A two-string barbed wire fence costs $40 per mile.

Goats, as extirpators of woody weeds (Corylus, Azalea) are frequently useful on mountain pastures.

Woody weeds damaging the pastures are kept in check by continuous mowing, especially if mowed in August. A limited use of fire, too, improves the pasture. Forest pastures are invaluable as fire lanes.

Pasturage of cattle extends in Pisgah Forest from May 1st to October 15th. Sheep and hogs require feeding only in February.

The revenue made per month amounts to: per head of cattle, fifty cents; horses, seventy-five cents; sheep, ten cents.

Where the growth of trees on a permanent pasture is too dense, deadening or coppicing is required. Where it is too little or where erosion sets in, the pasture must be abandoned for a number of years. Dead trees placed horizontally on pastured slopes safeguard the pasture.

In European and in Indian forests, pasture still plays a most important role, frequently as a prescriptive right encumbering forests owned by the Crown or by the aristocracy.

Relative to forest pasture in the Cascade Reserve of Oregon *see* "Forest Policy."

Forest pasture in the Pine woods of the South and of the Southwest is of utmost economic importance.

Forest pasturage requires regulation in the following points: Number of animals per acre; species of stock and of trees; season of pasturage; remuneration; closed years; firing; responsibility; supervision; salting; improvements; access.

D. Forest fruit raising:

I. Pecan.

Large investments are being made in Pecan plantations in the South. Usually seedlings three years old are planted fifty to sixty feet apart. Payable crops are expected fifteen years after planting. Cultivation and fertilization of Pecan orchards are required just as in apple orchards.

II. Apple-trees planted on freshly cutover woodlands (Northwest slopes) are said to be particularly promising.

III. Chestnuts. Chestnuts are either obtained from the woods where Chestnut trees are grown for timber, or from orchards. In Pisgah Forest seed years are said to occur every seven years. The nuts sell at fifty cents to one dollar per bushel. The mountaineers burn the woods to more readily uncover the nuts.

Orcharding combined with grafting of French Chestnuts (Castanea vesca) on the American species has been tried in Pennsylvania with little success owing to forest fires.

In Southern France a large revenue is obtained from the nuts ($5 to $6 annually from a good tree).

IV. Acorns. The acorns of the White Oaks are ground as a substitute for coffee (Postum Cereal 80%). In addition, acorns are of high value for pannage and in game preserves.

V. Berries. The crop of berries growing in the forest is locally leased to the highest bidder. The huckleberry crop is improved by periodical burning.

E. Maple sugar:

The production of sugar depends on the size and on the development of the individual trees, influenced by careful thinning. An underwood and a heavy layer of humus is helpful. Planted sugar orchards are rare and suffer from sun scald and from hardening soil.

F. Naval stores:

No means are known tending to increase the production of naval stores. The best yield is obtained from healthy, large trees.

G. Rubber and guttapercha.

H. Truffles and champignons.

I. Ginseng (Aralia quinquefolia):

Ginseng grows in the Alleghanies in well-sheltered north and northwest coves of greatest fertility. The young roots are easily transplanted into nursery beds. The cultivation of ginseng in the woods, however, is not practicable.

J. Sumach leaves:

The leaves, used for tanning on a large scale, are gathered on abandoned fields in Virginia. No care seems to be devoted to the reproduction.

K. Pharmaceutical weeds:

A large number of forest weeds have a pharmaceutical value and might be locally propagated and fostered.

L. Peat bogs:

Peat bogs reproduce themselves where the top layers only are taken off periodically. Small benches are left between the pits utilized.

M. Fish and game:

In the Prussian State forests, twelve per cent of the annual revenue is obtained from hunting and fishing leases. Private owners in the Adirondacks and in the South draw a large revenue from leasing the exclusive privilege of hunting and fishing. For particulars regarding the raising and nursing of Fish and Game *see* lectures on "Fish and Game Keeping."

Paragraph LXXIX. Combination of sylviculture and agriculture.

As the woodlot belongs to the farm, so does the farm embraced by woodland belong to the forest.

Strange as it sounds: The forester abroad is sometimes charged with the administration of more farmland than of woodland.

A fair practical knowledge of agriculture is indispensable for the administrator of forests. Truly agricultural land within the forest should be cleared in due course, in pursuance of the maxim that every acre of ground must be placed under the (permanently) most remunerative industry.

The forest farm produces victuals for the lumber camp and forage for the teams and yokes; it yields the best possible fire lanes.

Under these circumstances it is not to be wondered at that a local, permanent or temporary combination of sylviculture and agriculture is frequently indicated, in coppice forests as well as in high forests, in cultured forests as well as in culled forests.

A. Reasons prompting the forester to adopt " agriculture " may lie in the following moments:

I. Frequently it does not pay to eradicate the " weeds " in the forest previous to artificial or natural regeneration by n. s. r. In such cases, the forester may take advantage of the fertility stored up in the humus, using it for a nuuber of years for the production of field crops and freeing the soil incidentally from competing weeds.

II. Similarly the forester is often at a loss to save his regenerations from the attacks of wild or tame animals. Allowing the plantations to pass their earliest youth in the midst of farm crops which pay for the expense of protection from animals by immediate returns, protection for the plantations is obtainable at a reduced charge.

III. The fertility stored away in the accumulated humus, although exhaustible within three or four years, frequently furnishes a snug revenue (especially where farmland is scarce, as in all mountain districts) defraying the outlay, or part of the outlay, required for successful reforestation.

IV. In the prairies, agriculture must precede the tree plantation, which will not thrive in soil devoid of porosity. The plantation of trees, on the other hand, will protect the farm from drought in summer and from high winds during winter; it will shelter the stock during severe blizzards, etc.

Henry von Cotta, as early as 1819, advocated plantations of trees in rows twelve feet to fifty feet apart, the intervening spaces to be used for agriculture. The trees and the rows were to be decimated gradually, and were again to be reinforced in compliance with the requirements of the farm.

Cotta's plan might be successful where drought is to be dreaded during summer, scorching the grass meadow and the grain field.

B. Modern application:

I. Field crops intervening between two generations of the forest.

All over the pineries of the South where abandoned fields produce splendid polewoods of Pine, the woods are cut at the thirtieth to sixtieth year of the trees; the soil is then used for the production of corn, cotton or small grain for a number of years and thereafter allowed to revert to Pine planted by n. s. r. from adjoining woods. The same system is followed by thousands of farmers in the old country.

II. Field crops temporarily raised amongst and together with forest crops.

a. In coppice forests:

In Germany, the owners of coppice woods, after coppicing, frequently burn the debris on the ground, ploughing the soil roughly thereafter and using it for growing small grain or potatoes as long as the fresh stool shoots do not overshadow the farm crops too severely.

This system allows the farmer to continuously (although intermittently) produce field crops on steep slopes liable to wash, with the help of fertility furnished by the humus and by the activity of the tree roots.

b. In high forests:

1. In the early stages of sylviculture, acorns and pine seeds were frequently planted (like red clover) with barley, oats or summer rye. Compare Par. XV for details.

2. Sir D. Brandis has established in Burmah a system named "toungya" by which seedlings of Teak, planted with rice by native lessees on government reserves, obtain protection from wild animals and fires as well as from the Bamboo threatening to suffocate the seedlings.

3. A similar system has been practiced since 1810 in the German Rhine valley where splendid polewoods of White Oak have thus been raised. Here in years past the returns from toungya used to more than cover the expense of forest planting and protecting. The field crops shade the Oak slightly and tend to protect it from the effect of late frosts as well as from the attacks of grub worms (Melolonthidae).

4. In Western N. C., the expense of clearing the forest for field crops amounts to ten dollars or twenty dollars, according to the density of the growing stock and according to the yield derivable from the sale of timber removed.

On good forest soil a few years of corn crops are apt to refund the outlay incurred for clearing.

Thereafter the Pines, the Oaks, the Yellow Poplars and the Ashes of the adjoining woods will quickly produce a superior plantation of trees.

Where the soil is stocked with tree weeds, and where no immature trees must be sacrificed, the system can be strongly endorsed.

SILVICULTURE.

ALPHABETIC INDEX

INDEX

INDEX

INDEX

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