

EXERCISES IN WOOD-WORKING



WITH A SHORT TREATISE ON WOOD

IVIN SICKELS, M.S., M.D.

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*WRITTEN FOR MANUAL TRAINING CLASSES
IN SCHOOLS AND COLLEGES*

BY
IVIN SICKELS, M. S., M. D.

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PREFACE.

THE exercises in wood-working in this book were prepared by me during the summer of 1888 for the students of the College of the City of New York. Subsequent teaching suggested many changes and additions, until the manuscript was scarcely presentable. This manuscript has been copied for other schools ; and now, in order that those who have recently asked for it may receive it in better shape, this little volume is printed.

I am indebted to Mr. Bashford Dean for the part relating to injurious insects, which was written expressly for this book.

I. S.

NEW YORK, *September, 1889.*

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INTRODUCTION.

THE tendency of modern systems of education is toward a proper distribution of practical with theoretical training. The mind is to be aided in its development by the action of the eye and hand ; and, in fact, all the special senses are employed in objective teaching and manual exercises. In school, the eye does more than interpret the printed page: it recognizes the form and color of objects, it must calculate their size, proportion, and distance, by observing and comparing them ; the hand is required to do more than writing: it is taught to appreciate the weight, hardness, and other properties of objects, by actual contact with them. At first the introduction of drawing, modeling, and the use of tools, into the courses of study was experimental ; but, having passed beyond that stage, these exercises are now known to be efficient aids to a more natural and rapid as well as stronger mental development.

There are some who, after being educated in the abstract way, can apply their training successfully to practical pursuits, who see no necessity for manual or industrial training in the schools, and who claim that superior and sufficient development may be obtained by the study of mercantile methods and the classics. These, however, form a very small percentage of the people, and systems of education must be arranged to stimulate all intellects, and not measured by the accomplishments of a few. Our best educators recognize this fact, and are modifying old systems by the greater introduction of manual elements. No one doubts the value of practical qualities, not only in ordinary people, but also in prominent leaders, who must be thoroughly practical — a fact so aptly illustrated by prosperous manufacturers and merchants, successful engineers, great generals, and eminent statesmen.

Manual training for the early cultivation of these practical qualities in students takes a place in the regular courses of study: by means of it the reasoning power is more easily awakened, knowledge of objects and the facts connected with them are more readily understood and remembered ; and, above all, the accuracy and precision demanded by the practical studies lead to closer observation and exactness in others. This training begins in the lowest grade and continues in its various applications through all the classes, until in the higher grades we find sufficient physical strength to handle the ordinary wood-working tools.

The prime object of all manual training, especially in this country, is to aid mental development, and while this fact must not be lost sight of, the training should be in some useful art, or in some exercises which are introductory to the useful arts.

Perhaps the most valuable of these studies is industrial drawing, which is in itself a sort of universal language, a medium between thought and execution. Its study cultivates precision and is well calculated to develop sound and accurate ideas. Drawing naturally precedes construction, it prepares the way for the work of the engineer, manufacturer, or builder. Even the ideas of the inventor are jotted down in a chance sketch, which is added to and modified at leisure, leading to the finished sketch, from which the skilled draughtsman produces the designs for the execution of the work.

The studies of drawing and wood-working are closely connected, and may be taught together with great advantage to both. A simple object is roughly sketched on paper, its measurements accurately made and marked on the sketch ; from this a drawing is made with instruments either full size or to a scale, which is used in the workshop as a guide to the construction of the object. Skill in sketching is a valuable acquirement, and should be taught early in the course of industrial drawing. These sketches should, if possible, be made from real objects instead of charts, and should always be accompanied by measurements. In sketching it is well, first, to determine the number of diagrams necessary to show the form or structure of the object, and allot for each a certain space on the paper ; second, to place each sketch in the middle of its space, of which it should occupy about one half, thus leaving a margin for notes, measurements, and small details ; third, to draw the relative proportions of the object as accurately as possible ; fourth, to mark on the sketch the measurements of each part.

Wood-working from the simple constructions of earliest times has advanced with the necessities and customs of nations, until at present it includes the complicated structures of modern requirements. Throughout all wood-working trades we find certain general principles regarding the cutting action of tools on wood, and the joining of different pieces ; and, since those principles are more easily taught by carpentry and joinery, these branches have been generally adopted as educational aids.

The very extensive use of wood for building has given rise in this country to a craft of carpenters whose improved tools and methods of work are superior in many respects to those of European workmen. Based upon these methods, workshop practice in schools and colleges as applied to wood-work does not stop with carpentry: its design is to prepare the way for the entire field of mechanical arts ; so that carpentry and joinery are followed by turnery, carving, and possibly a few lessons in pattern-making. These should be followed by metal-work, such as forging, chipping, filing, and, finally, with the elements of machine-work. The study of mechanics as thus taught in the educational workshop should be applied correctly, by methods which are the actual but intelligent practice of the operating mechanic. As to the time required, it can not be expected that the three to five hours per week spent in the workshop are going to make mechanics ; far from it: several years of labor and experience are necessary to produce skilled workmen in any of the arts.

This book deals with carpentry and joinery, and is divided into two parts:

The First Part treats of the structure, properties, and kinds of wood ; its manufactures and economic relations to other substances, parasitic plants and insects ; and means of preserving wood.

The Second Part contains the exercises, preceded by a description of tools, and the manner of drawing used to illustrate the exercises.

These exercises are based upon American methods of work and have been taught as follows: Each exercise was explained, illustrated by sketches on the blackboard, and then executed by the students. As the exercises advanced, the blackboard sketches were prepared with more detail, each being shown with its measurements designated. The students copied these

sketches and noted down such of the verbal directions as they could. With the higher exercises it was found necessary to issue duplicate copies, describing and illustrating each step in construction, and also to exemplify by models made by the instructor.

Exercises 1 to 8 introduce the chief wood-working tools and methods of marking. These exercises should be executed with much care and patience, and if necessary repeated, to insure better results in subsequent work.

Following exercise 8 are directions for sharpening tools. But students should not attempt to sharpen tools until they have had considerable practice in the use of them ; especially saw filing, which requires remarkably good judgment, keen eye-sight, and a steady hand.

Exercises 9 to 20 give instructions for marking out and shaping simple joints.

Exercises 21 to 27 instruct in the methods employed in uniting several pieces to make a complete structure.

Exercises 28 to 35 give the details of ordinary house-carpentry, from which the student may obtain particulars for the construction of models, and the apprentice the actual building of the various parts making up a wooden dwelling.

Exercise 36 shows the use of the frame-saw, and methods of bending wood.

Exercise 37 gives an example of pattern-work, and illustrates the manner of uniting pieces for economy of labor.

Exercise 38 instructs in shaping by the use of templets.

Exercise 39 treats of veneering, followed by directions for painting and polishing.

PART FIRST.

STRUCTURE OF WOOD.

If we examine the stem of a young plant, we find three distinct tissues composing it: On the outside is the bark or protecting tissue (*a*, [Fig. 3](#)); inside there is a soft material, made up of many-sided, thin-walled cells, which constitute the living portion (*b*, [Fig. 3](#)); and arranged in a circle in this soft tissue are several fibrous bundles (*c*, [Fig. 3](#)), giving to the stem its strength to support the branches and leaves. Because of differences in the character of these bundles we separate stems into three classes; and the pine, palm, and oak may be taken as types of each.

In the pine and oak the bundles are similarly arranged, and consist of an outer portion called **bast** (*d*, [Fig. 3](#)), and an inner portion called **wood** (*e*, [Fig. 3](#)); between these is a thin layer of active cells, which multiply by division to form the bast and wood; this layer is called **cambium** (*f*, [Fig. 3](#)), and adds each year to the size of the bundle. In the palm the bundles arise from active cells at the growing point of the stem, and continue down the stem, sometimes becoming smaller, but retaining a rounded form.

As the stems grow older and larger, we find, in the pine, that new and branching bundles appear between the first ones, forming, during the season, a circle of bundles, which constitutes the first **annual ring**. This ring is interrupted by plates of tissue communicating between the pith, on the inside of the ring, and the soft tissue on the outside. In a cross-section of the stem these plates are seen as lines, called **medullary rays**, radiating from the center toward the bark. At the end of the season growth stops, to be resumed again in the spring. The slow and condensed growth of summer, and the rapid, open growth of spring, give rise to a peculiar mark in the bundles which indicates each year's increase, so that by counting these marks or the annual rings we may ascertain the age of a tree.

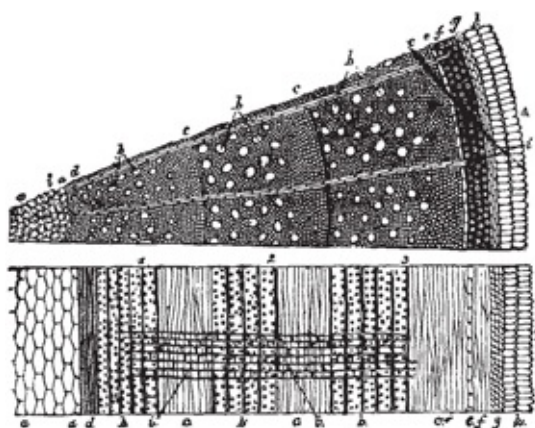


FIG. 1. — Diagram of a stem with a cambium layer. A, section cut across the bundles; B, section in the direction of the bundles. 1, 2, 3, first, second, and third annual rings; *a, a*, pith; *b, b*, pitted vessels; *c, c*, wood-cells; *d*, spiral vessels, found only in the first annual ring; *e*, cambium-cells; *f, g, h*, layers of bark; *i, i*, medullary ray. (After Carpenter.)

The last few rings formed are engaged in transporting or storing up nourishment, and give rise

to what is called the **sap-wood**. The rings inside of the sap-wood serve only for support, and make up the **heart-wood** of the tree.

In the palm, new bundles arise, placed irregularly in the soft tissue or **pith**, and by tracing these bundles throughout the plant we see that they extend, usually without branching, from the apex of the leaf to the small ends of the roots, so that for each new leaf there will be the stem new bundles.

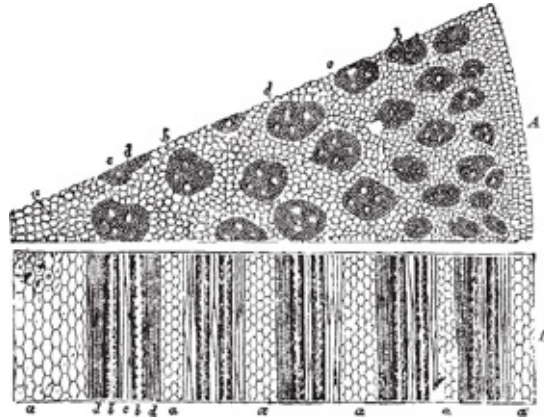


FIG. 2. — Diagram of a palm-stem. *A*, cross-section ; *B*, longitudinal section ; *a, a*, soft tissue ; *b, b*, vessels or tubes with pitted sides ; *c, c*, wood-cells or fibers ; *d, d*, vessels with spiral markings. (After Carpenter.)

In the oak we have the same appearance regarding the annual rings and medullary rays as the pine:

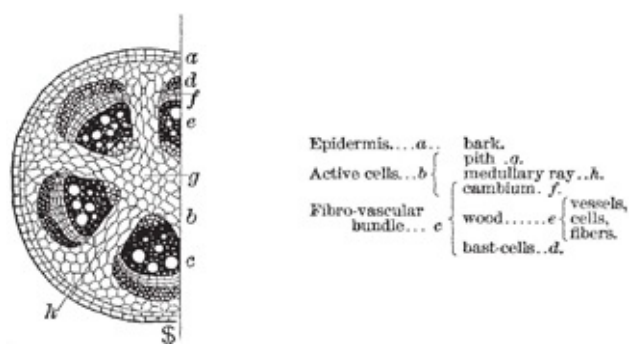


FIG. 3. — Section of stem.

Examining more closely these wood-forming bundles, we find them composed of cells with a variety of forms and walls of varying thickness and peculiar markings. In the pine group the cells are long, with pointed ends, and walls marked by characteristic elevations called **bordered pits** (Fig. 4). These pits arise during the thickening of the cell-wall, which can not take place on the thin circular membranes (Fig. 10, *c*), through which the sap passes, but forms arches with open tops over them, and thus gives the bordered appearance. In the heart-wood these thin membranes have broken down, allowing a free passage of air or water through the cells. In spaces between the wood-cells there are, in most of the pines, canals containing resin dissolved in turpentine. The thin plates of tissue forming the medullary rays are composed of small cells, with thin walls in the outer annual rings, but in the heart-wood with walls very much thickened.

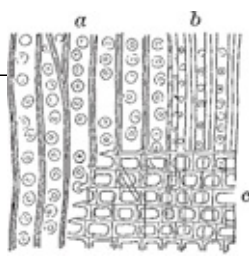


FIG. 4.

FIG. 4. — Section of pine-wood cut parallel with the medullary plates. *a*, spring growth, with large bordered pits ; *b*, summer growth, with smaller bordered pits ; *c*, medullary tissue.

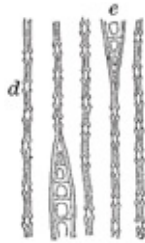


FIG. 5.

FIG. 5. — Section at right angles with the medullary plates. *d*, bordered pits ; *e*, medullary tissue.

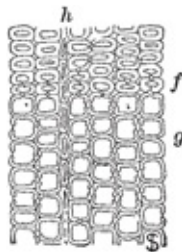


FIG. 6.

FIG. 6. — Cross-section of the same. *f*, summer growth ; *g*, spring growth ; *h*, medullary ray.

The isolated bundles of the palm are composed of various elements, some of which simply support, as the bast and wood fibers ; others support and conduct, as the vessels and wood cells ; these latter convey air, and water charged with mineral matters absorbed by the roots

The bast-fibers are on the outside, surrounding the bundle, and are very long, narrow, many-sided cells, with pointed ends, the walls very much thickened and marked with oblique pores. The wood-fibers are on the inside of the bundle, similar to the bast-cells in every respect except that they are shorter, and occasionally used for conducting and storing up nourishment. The vessels or tubes are large and few, and present varied markings ; the larger are pitted, the smaller either ringed, spiral, netted, or ladder-form. The wood-cells are like those of the pine group, but with simple in place of bordered pits. There are present, also, sieve-tubes with clusters of small perforations in sides and ends, and a group of long, thin-walled cells similar to the cambium-cells of the pine and oak. Frequently in the vicinity of the vessels are found thin-walled cells with blunt ends, separated from the vessels and surrounding cells by membranous pores ; these cells, which are somewhat similar

cambium-cells, serve the purpose of conducting and storing up the organic materials formed in the leaves.

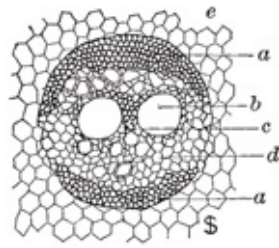


FIG. 7. — Palm-bundle, a, a, bast ; b, pitted vessel ; c, wood-cells ; d, smaller vessels ; e, soft tissue.

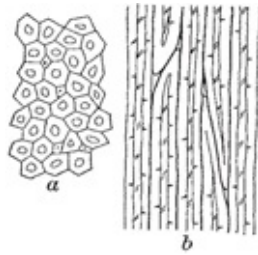


FIG. 8. — Bast-fibers.

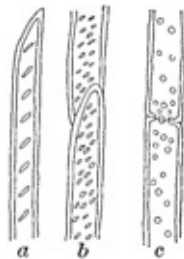


FIG. 9. — Pitted vessels.

In the oak group the wood is composed of compact bundles made up of the same fiber cells, and vessels found in the palm, with the exception of the bast-fibers, which are formed outside of the cambium zone and constitute the inner bark. In the spring growth the vessels are large and numerous; in the autumn they are much smaller, and in some cases may be absent. By this variation in the size and position of the bundles the annual rings become distinctly marked. The medullary rays in the heart-wood vary in thickness, and in many of the woods the cells composing them become solid.

COMPOSITION OF WOOD.

Newly formed cells have the wall composed of **cellulose**, a substance similar to starch in composition. The contents of the cell are made up of a number of substances, the chief of which are albuminoids, starchy matters, oils, and water with dissolved sugars, gums, and acids.

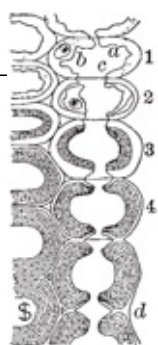


FIG. 10. — Diagram showing growth of the cell-wall.

1. Cambium-cell: *a*, protoplasm or living contents of the cell ; *b*, nucleus in the proto-plasm ; *c*, thin membrane through which the sap passes. In the heart-wood this membrane has broken down, as at *d*.
2. Protoplasm forming a wall of cellulose.
3. Protoplasm has disappeared. Cellulose changing into lignin.
4. Cell-wall composed of lignin and thin membrane.

In the heart-wood the contents have disappeared, air taking their place, and the cell-wall has become very much thickened by a deposit within the cellulose of a dense substance called **lignin**, which gives to wood its elasticity and hardness.

In the living tree, air and water are present in varying quantities, depending on the season and kind of wood. The amount of water is frequently as much as fifty per cent. During the seasoning of pine, about twenty per cent of water is removed from the wood. This may be called **free water**, because it exists in the plant with all the ordinary properties of water. But there is also in pine-wood about the same amount of water, which is chemically combined with carbon to form cellulose and lignin. The presence of this **modified water** may be demonstrated by placing the wood in a partially closed iron vessel, and heating it red hot ; the wood is reduced to charcoal, while water is given off, together with a small quantity of gaseous oils, and other matters.

The elementary composition of wood varies according to the kind, the soluble matters in the soil, and the amount of moisture absorbed by the tree. Generally wood contains large quantities in proportion of carbon, hydrogen, and oxygen ; less of nitrogen, sulphur, and potassium ; and small quantities of iron, phosphorus, calcium, sodium, and silicon, with traces of many other elements.

If wood is burned in the open air, the carbon, hydrogen, nitrogen, sulphur, and part of the oxygen are driven off in gaseous form ; the other elements remain, and constitute the **ash**, of which the principal ingredient is potassium.

The amount of ash is greater in the palms and least in the pines. The percentage of a few a

as follows :

Oregon pine	0.08
Red cedar	0.13
Redwood	0.14
Chestnut	0.18
White pine	0.19
Whitewood	0.23
White oak	0.41
Hickory	0.73
Black walnut	0.79
Palmetto	7.66
Black iron-wood	8.31
Spanish-bayonet	8.94

BRANCHING OF STEMS.

In the middle of a forest, trees grow straight, tall, and slender, as in [Fig. 12](#), because it is necessary for them to push up the tops in order that they may receive sufficient sunlight, and to enable the leaves to digest the plant-food and increase the diameter and height of the stems. Lower branches last only a few years, then die, and are broken off (*b*, [Fig. 12](#)). On the margins of the forest and in open places, trees send out numerous branches, and stems become large in diameter, but remain short ([Fig. 11](#)). The bordering trees, while they serve as a protection from the wind for those inside, furnish knotty and cross-grained lumber ; those inside produce the straight-grained and valuable wood ([Fig. 13](#)). Members of the palm group rarely have branching stems. In growth, the stems remain long and slender, but frequently are larger at the top than at the base.



FIG. 11. — Shape of a tree on the border of a forest. *a*, broken branch exposing surfaces for boring insects or fungus spores.



FIG. 12.

FIG. 12. — Young forest tree, *b, b*, branches die for want of sunlight.



FIG. 13.

FIG. 13. — Shape of forest tree with straight stem and crown of small branches and leaves.

AGE OF TREES.

Like animals, in growth and development plants are subject to influences of climate and nourishment. In its proper latitude, and with an abundance of water and food in the soil, a tree adds to its annual growth and lives to a great age. But when the soil becomes exhausted of the necessary elements, or a more robust species crowds roots and leaves, then a tree begins to show signs of decay. It is difficult to establish rules regarding the proper age for cutting. For timber, most trees are considered fit at about one hundred years, although oak may furnish excellent timber at two hundred years. The purpose for which the wood is to be cut determines the proper age. Young trees show a closer grain and give a more elastic wood than old ones. Very old trees, although apparently sound, are found to be partially decayed in the middle of the trunk, so that the elasticity and hardness of the wood are replaced by characteristic brittleness.

DECAY OF TREES.

As long as a tree is in a healthy condition, its top or crown retains its small branches, but when these refuse to send forth leaves, and break off, it is a sign of decay, and the tree should be cut down and put to some use ; for, if allowed to stand, its decay, aided by parasitic

insects, will proceed rapidly until there remains nothing but a shell, composed of the growing zone and a few of the last annual rings, and its value for any purpose will become very much lessened or entirely lost.

Breaking or sawing off a branch and leaving the wound exposed will furnish an opportunity for fungus spores or boring insects to begin the destruction of the wood.

Cutting down trees on the border of a forest, or clearing a large space within it, is destructive to the tall trees remaining exposed to the winds and elements. The swaying of the stems in a storm causes the tender root-hairs to be broken off, thus preventing absorption of sufficient nourishment by the root, and shortening the life of the tree.

SEASON FOR CUTTING.

The proper time of the year for cutting down trees is an important matter. In the spring and late summer the outer portion of the wood is charged with elements which tend to hasten its decay. In the drier summer months and in winter the growing and conducting cells are less active or altogether dormant, and better wood may be secured if cut during those times of the year. Oak is said to be more durable if cut just after the leaves have fallen.

The trees are cut with axe or saw, and skill is required to fell a tree so that it will come safely to the ground, and not hang suspended to neighboring branches or crush young trees in its fall. An experienced woodman will direct the falling tree exactly where he wishes. He cuts on one side and about at a right angle to the direction in which he wishes the tree to fall ; next he cuts on the opposite side, and, if necessary, a few inches higher.

The tree, after falling, is cleared of its branches and sawed into lengths, according to the future use of the wood.

MILLING.

If near a stream, the logs are rolled or drawn to the water and floated to the mill, where they are examined and grouped according to fitness for special uses. A long immersion of the logs in water removes soluble substances in the sapwood, but is said to injure the heart-wood by rendering it less elastic. **Water**, however, is the easiest and cheapest means of transporting logs. In the absence of an available stream, the logs are carried on wagons or sleds to a railway or directly to the mill.

The old-time mill, with its single upright saw and ancient water-wheel, is seldom seen nowadays ; it has given way to gang and circular saws, and even to giant band-saws, run by turbine or steam. Frequently portable engines and saws are employed on the ground where the trees are cut, thus saving the transportation of the waste portions of the logs.

Logs are sawed into either **timber**, **planks**, or **boards**, and these constitute **lumber**. Timber includes all of the largest sizes, such as beams and joists. Planks are wide, of varying lengths, and over one inch in thickness. Boards are one inch or less in thickness, and of varying

lengths and widths. Lumber may be **resawed** into the many smaller sizes which are to be found in the seasoning and storing yards.

The rough-sawed lumber may be planed at a mill, and is then called **dressed** lumber, of which there is a great variety, adapted to almost every purpose for which wood is used. Dressed planks and boards when free of all defects are called **clear**, and their regular sizes are $\frac{5}{8}$, $\frac{7}{8}$, $1\frac{1}{8}$, $1\frac{3}{8}$, and $1\frac{7}{8}$ inches, which are one eighth of an inch less in thickness than sawed lumber. One-half-inch dressed is made by resawing one-and-a-quarter-inch lumber.

DRYING OF WOOD.

In the preparation of lumber for use, it is necessary to remove its moisture, after which the wood is **seasoned**. The planks and boards after sawing are placed in large square piles in the open air, each layer separated by three or four narrow strips or boards laid in the opposite direction. By this means a free circulation of air takes place throughout the pile ; the drying is gradual and thorough, if allowed sufficient time. For ordinary carpentry, two years is considered enough, but for joinery at least four years should be allotted to the seasoning. Many processes have been devised to hasten the evaporation — such as kiln-drying, in which the wood is placed in chambers heated by steam or hot air, or by the employment of vacuum pumps together with heat. All are inferior, however, to the open-air seasoning, in that they cause a rapid drying of the surface and ends, with a slow or imperfect drying of the interior, thus impairing both the strength and elasticity of the wood.

It is difficult to give rules for testing wood to determine whether it has been properly seasoned or not. One way is to push a knife-blade into the wood, and note how much it sticks when withdrawn. Another is to cut a shaving from the board, and note its elasticity, brittleness, or strength. Experienced workmen crush shavings in their hands to determine the character of the wood.

As the wood loses its water it shrinks perceptibly, much more in the direction of the annual rings than in the direction of the medullary rays, and very little, if at all, in the direction of the fibers. If we examine the end of a log which has been exposed to the weather, we will find cracks extending from the center toward the circumference, and which penetrate from a few inches to a foot or more into the log ([Fig. 14](#)). These cracks, called **wind-checks**, are seen in planks and boards, and cause the ends to become waste wood. To prevent this rapid drying, the ends of the logs are tarred or painted. If the lumber is piled soon after sawing, these wind-checks are smaller, and the waste portion is consequently less.

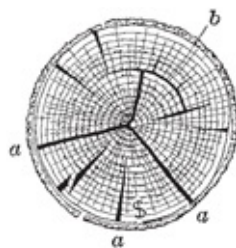


FIG. 14. — End of oak-log exposed to the weather. a, wind-check ; b, shake.

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