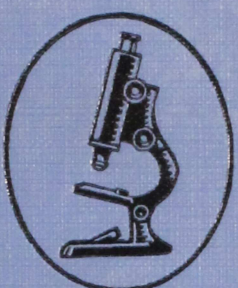
WONDERS THROUGH THE *Microscope*



HANDYMAN'S MODERN MANUALS

WONDERS
THROUGH THE MICROSCOPE

WONDERS THROUGH THE MICROSCOPE

A complete manual for amateurs. How to use equipment, secure and preserve specimens, take photomicrographs, etc.

PREPARED BY THE EDITORIAL STAFF
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INTRODUCTION

AS the reader of this volume becomes familiar with the microscope, he will find it one of the most fascinating, informative, and entertaining instruments known to man. With it he can see amazing things, and wonders he never imagined even in his wildest dreams. The microscope is the leader of the world's most thrilling hobby movement. It has followers everywhere, and not one of them ever regretted entering the world to which it gives access.

A professor of psychology once said that everyone should have a hobby, but that an active hobby is far more beneficial than one that consists merely of collecting things. There are few hobbies more active than microscopy, and certainly none that is more fascinating, instructive, or useful. Furthermore, the cost need not be great; outside of the microscope itself, it can be almost nothing.

Anyone can learn to use a microscope successfully. After all, the most complicated and costly research microscope is essentially nothing more than a magnifying device. So is the instrument the amateur uses. The theory of the microscope includes a lot of information about resolving power and numerical aperture and color correction of lenses; but you can enjoy the antics of a live rotifer just as well before you learn about such things.

When you buy a microscope, get the best you can afford. You can skimp on such things as illuminators, slide boxes, scalpels, and dissecting needles because you can make them yourself, largely from odds and ends; but it takes a capable manufacturer of optical instruments to make a good microscope.

You will find it helpful to procure a textbook of zoology and one of botany. Then you can identify many of the wonders you will discover with your magic lenses. As you become more and more a confirmed microscope hobbyist, you will find it desirable to get some of the more advanced books, dealing with color filters and slide making and other phases of microscopy.

In this book, an attempt has been made to introduce you to a few of the wonders of the World of Little Things, and to make it easy for you to discover other wonders for yourself. You will not find this difficult. Indeed, you will discover that there is beauty and fascination in almost every commonplace object, if you magnify it a little. Before long, you will regret that you did not begin to use a microscope years ago.

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WONDERS THROUGH THE MICROSCOPE

CHAPTER I

SETTING UP YOUR WONDER WORKSHOP

DID you ever dream of sitting by your fireside, pressing a magic button, and traveling to far-away lands where you would see beautiful cathedrals, ferocious beasts, teeming life in strange settings, and jungle plants both fantastic and beautiful? After picturing such wonderful sights in your imagination, didn't the everyday world that surrounds you seem dull and insignificant by comparison?

Far more powerful than any button that would bring you such thrills is the compound microscope, a modest-appearing instrument of metal and glass. Looking through this magic tube, you are transported instantly, not only to new lands but to entirely new worlds, far more wonderful than the one to which you are accustomed. You find that the crystalline structure of a piece of cuttlefish shell surpasses in beauty any man-made cathedral; that tiny creatures stalking their prey in a drop of water are so ferocious that the jungle lion is a mere kitten in comparison; that there are living things in the most unsuspected places, excelling in beauty and interest the human inhabitants of any city

or land you could name; and that there are microscopic plants vastly more beautiful and important than any tree or shrub the forest can offer.

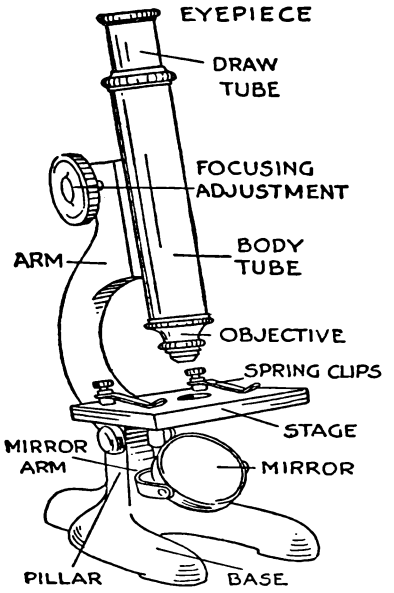
If you are looking for rare beauty, action, life, color; if you would be thrilled by witnessing the creation of new life forms, the microscope is the magic key you want. Don't worry if you are not an expert biologist or botanist who knows every plant and animal by its first and second names: you can get a lot of thrills out of watching Saccharomyces cerevisiae sprout a new bud even if you know it only as a yeast plant.

"But what will it cost?" you ask. "Surely the traveler who visits new worlds needs a purse with elastic strings."

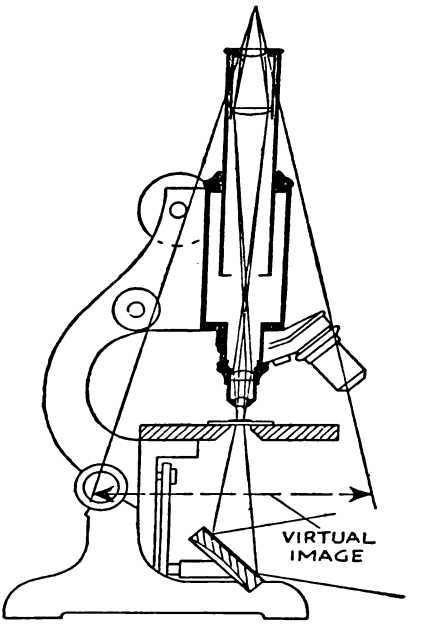
The good news is that low excursion rates have been arranged to this microscopic wonderland. You can stay as long as you like and make as many round trips as you desire, on the same ticket. Manufacturers have placed upon the market dozens of different microscopes, ranging in price from a few dollars to a few hundred. You will be wise to get the best you can afford. Twenty-five dollars is not too much to pay for an instrument that will admit you to a whole new world. Neither is a hundred dollars—if you have the hundred.

A gold and platinum microscope would be useless if it had pop-bottle lenses. So when selecting an instrument, pay particular attention to its optical equipment. A compound microscope consists of an objective and an eyepiece. The objective magnifies, say, 10 diameters; and the eyepiece magnifies the image formed by the objective, say, 7½ diameters. The total magnifica-

tion of the microscope, then, is 75 diameters. It is better to have a 75-power microscope with good quality lenses than a 1,000-power instrument with lenses that would not focus sharply on anything. Incidentally,



THE MICROSCOPE



PATH OF LIGHT

you could spend the rest of your life looking at things magnified only 75 diameters, and not exhaust half of the material at hand. Comparison of several microscopes that the dealer has to offer will tell you quickly which is the best. Examine the same object at the same magnification, in making the comparisons. If you can-

not visit a microscope dealer personally, stick to the products of reliable manufacturers.

But the microscope is merely the magic wand that transports you to the world of little things. You will need some luggage, nothing very costly, but enough to make your journey easy and pleasant. Fortunately, you can make a lot of the equipment yourself, thus releasing dollars and cents for investment in the all-important microscope.

For unearthing tiny insects, miniature plants, and other objects that are difficult to see with the unaided eye, you will find a hand lens invaluable. A reading glass will do, although a folding magnifier that you can carry around in your pocket will be more useful. Another type is the tripod magnifier that consists of a lens in a mount equipped with three legs so that it will rest on a table or the surface of the object being examined. It will cost 75 cents or so. This magnifier also is useful for focusing an image on the ground glass of a photomicrographic camera.

A dissecting microscope is nothing more than a lens magnifying 5 to 10 diameters, attached to a stand having a piece of glass to support the object and a mirror for directing light up through the object and lens. For dissecting out insect parts, tearing down flowers in order to uncover some gem of nature, and for rapid examination of articles to see whether they are worth magnifying further, the dissecting microscope is extremely convenient. You can buy the instrument ready-made for about three dollars, or you can construct one largely from scrap material. (See Chapter IX.)

Your journey through the microscopic world will not

be entirely one of sitting back in an easy chair and watching the sights go by. At times you will have to play the part of a butcher or surgeon. You will have to slice off thin sections from the bits of beef, plant twigs, and insects that you want to examine in detail. If someone suggests that you ought to look at the gizzard of a cricket and see if it has any grinding teeth, you will have to become for the moment a skillful surgeon. You will be forever tearing down the structures of insects so that you may look at their antennae, where sometimes thousands of sense organs are located, or at their many-lensed eyes that seem to gaze in all directions at once.

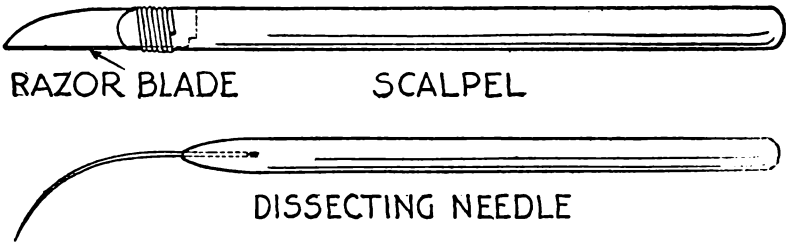
To do all of these things you will need tools—dissecting needles, sharp-pointed tweezers, droppers, scalpels, brushes, glass rods, and tiny shears. You can make most of these things yourself; and the ones you cannot make conveniently cost only a few cents.

You really ought to have two pairs of tweezers. A heavy pair, with rounded points and grooved jaws, will be useful for lifting large objects and for fishing specimens from the bottoms of bottles and jars. For delicate work, a smaller pair of sharp-pointed tweezers is essential. The tips should be needlelike. If necessary, file and grind them until they are of that form. Be sure that they close squarely. Often you can obtain tweezers of just the right type at a jewelers' supply company easier than anywhere else.

You can manufacture several dissecting needles for almost nothing. Get a few large darning needles and force their eye ends into wooden handles, the size and shape of a lead pencil. It may be well to cut the eye part off so that it does not enlarge the hole too much.

Some of the needles should be bent so that their points are at right angles to the handles. To do this, heat a needle in an alcohol or gas flame until it is red hot, then bend with pliers. Heat again to redness and plunge quickly into water to restore the temper. Another instrument that you will find convenient consists of a piece of fine wire having a small loop at one end, the other end being inserted into a handle. The loop is used for picking up liquids in quantities smaller than a drop. One of the wire strands from a flexible electric cord can be used.

One or more medicine droppers should be in every microscopist's kit. Probably the tips of those you buy



will be too large, or will end in a little ball. Heat the glass in a flame and draw it out until the hole is small enough. Let the glass harden and then break it in two at the desired point. One dropper should have a curved end.

The microscope worker's butcher knife is known as a scalpel or dissecting knife. You can make one by mounting a single-edged razor blade in a handle, or by breaking a blade so that you get a long, slender strip having one edge sharpened. Clamp the blade in a vise and use pliers for breaking it. Grind the rough edge

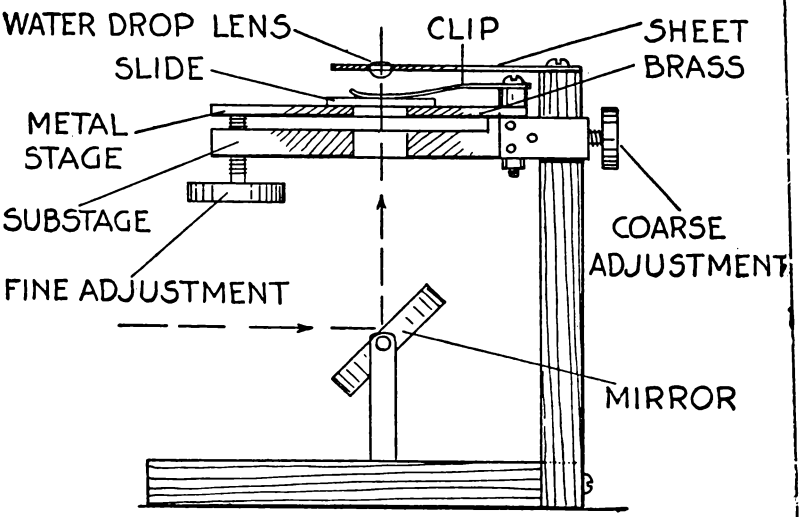
smooth. For a handle, use a piece of wood split at one end. Slip the blade into the split end and bind tightly with a fine wire or strong thread.

Artists' brushes, small and round, are useful for picking bits of dirt off microscope lenses, for picking up objects too delicate to handle with tweezers, and for forming shellac cells on slides or applying asphaltum varnish around cover glasses. A useful stirring rod can be made of a piece of glass tubing whose ends have been melted shut in a gas flame; or a piece of solid rod with its ends rounded.

Essential "dishware" for your microscope laboratory includes a number of bottles having good corks or screw covers to hold shellac, varnish, and other reagents, as well as insects pickled in alcohol; a few bottles equipped with dropper stoppers, for alcohol, xylol, and stains; some empty, wide-mouth bottles and jars, for specimens; and perhaps one or two petri dishes and watch glasses. Sometimes you can find the last two items at drug stores.

The stage upon which the microscopic world parades its wonders for your enjoyment is a little piece of glass measuring generally 1 x 3 inches. This is the microscope slide or slip. Then, in order to compress the drop of water into a thin layer, or protect whatever else you are inspecting, a thin circle or square of glass—the cover glass—rests over the object. You can buy slides by the dozen or the gross or you can make some from window glass, being sure to round the edges with a file dipped in turpentine containing some dissolved camphor, or with a wet grindstone. Cover glasses are sold by the dozen or by weight. A half-ounce contains enough to last a long time. Because

you will make a permanent slide now and then, and will want to mark it for identification, you will need some small gummed labels, measuring about ¾ x ¾ inches.



THE SIMPLEST MICROSCOPE

The fascinating business of slide-making and specimen-preserving requires a few reagents or chemicals. You will need, to start with, some alcohol, xylol (xylene), Canada balsam, and perhaps shellac, asphalt varnish, glycerin, liquid petrolatum, and various biological stains such as carmine, haematoxylin, and eosin. You can get along very nicely for a time with only the first three. The xylol or xylene is a solvent used for thinning the balsam. It will also dissolve a lot of other things including paraffin and the paint on

your desk top. The balsam should be of the filtered type prepared specially for microscope slide-making. The shellac, either orange or white, is the type used by painters. Asphalt varnish is sold by dealers in microscope supplies. As for the stains, you can buy them from the same dealers, or secure them through your local druggist.

When not in use, your microscope and its equipment should be kept where dust and grit cannot fall upon them. Drawers usually are available for the accessories, and the microscope itself should be kept in the case in which it was sold. However, you may find it inconvenient to return the instrument to its box every time you are through using it. An easier way is to set a glass bell jar over it. Another type of satisfactory dust shield can be made by covering the sides and top of a wire lampshade frame, of sufficient size to enclose the microscope, with closely woven cloth that does not produce lint excessively.

Now that you have a microscope and a collection of tools that will help you get the most out of it, you need a place in which to do your exploring. One thing in favor of the microscope is the fact that it can be used almost anywhere, from the kitchen table to the laboratory bench, provided there is sufficient light to illuminate the specimens. You should set up, as soon as possible, a special microscope table, one with many drawers and a good-sized top. It would be ideal if you could fit up an entire room as a micro-laboratory. You will find it more comfortable to work on a table whose top is painted black or some other dark color. The table should be placed near a window, to take advantage of daylight. At night, it should be illuminated by

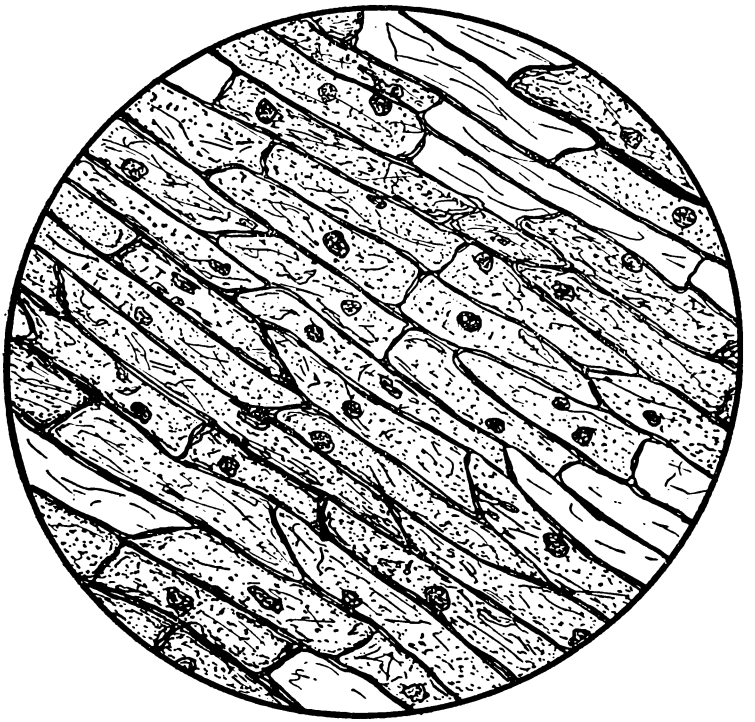
one or more overhead lamps placed so that their rays are not reflected into your eyes from glass slides, dishes, and similar shiny objects lying on the table top. The table and stool or chair should be of the correct height to bring the microscope eyepiece just to your eye when you bend over it. A satisfactory table height is 30 inches. Near the table, on the wall, you can install cupboards or shelves for holding all kinds of odds and ends that will be useful in your microscope work.

If you go camping or otherwise travel, by all means take your microscope along. Strange places always are swarming with tiny wonders waiting to become targets for your lenses. A microscope kit will enable you to transport your equipment with ease and safety. This consists of a strong box or case, equipped with a handle and fitted with drawers for holding slides, instruments, bottles and note paper; and clips for securing in place the microscope, illuminator, and other large pieces. The kit, in fact, can serve as your microscope laboratory at home as well as elsewhere, being stored in a closet or corner when not in use.

How about a bit of exploring now you have your laboratory set up?

Can you think of something that is particularly ugly? An onion? All right, procure an onion, either dry or fresh, and, with tweezers, peel off a little piece of the thin, almost transparent film that covers the white layers of the bulb. Wash a microscope slide with soap and water and dry with a piece of old linen, being careful not to smudge the glass with your fingers afterwards. Take a cover glass, preferably a square one, and wash and dry it the same way. Hold the glass care-

fully but firmly by its edges, between your thumb and finger, while cleaning it. Place a drop of water on the center of the slide, lay the piece of onion skin in it,



ONION SKIN

and drop the cover glass carefully over the specimen. The water will spread out and perhaps ooze from the cover glass edges, and the piece of onion skin will be pressed flat against the slide. Carefully force the slide

beneath the clips on the microscope stage, centering the bit of onion skin beneath the lens.

Still watching the slide and lens, turn the focusing screw until the objective of the microscope is within about 1/8 inch of the cover glass. Now look into the microscope and adjust the substage mirror so that the field of view is filled with light. Slowly rotate the focusing knob so that it moves the tube UPWARD. With almost breath-taking suddenness, the onion skin will glide into view.

Maybe you won't believe at first that it is the onion skin, for you probably will not be expecting anything so beautiful from so commonplace an object. Row upon row of cells marches across the field of view, like the flat stones of a garden wall. By focusing carefully up or down, you can examine first the top surfaces and outlines of the cells, then their contents. In many of the cells you will see, if the illumination is not too strong, little spots, some round, others flattened a little on one side or irregular in outline, and perhaps a few that look as though they were split through the middle. These are the cell nuclei. To make the nucleus and other parts of an onion cell easier to see, you can perform a bit of magic involving a method frequently employed in large laboratories: you can stain them.

Dilute some tincture of iodine with five times its volume of water. Remove the cover glass from the onion skin specimen and hold the slide high over a flame, letting the gentle heat evaporate the excess water, but not letting the onion skin dry completely. Drop some of the iodine solution on the specimen, let it remain for a minute or two, and then wash off with clear water. Replace the cover glass and look at the

cells. You can now see the nuclei distinctly, as brown or yellowish spots, while the other cell contents will show a similar coloring.

Wasn't that peek into the microscopic wonderland worth all of the effort? And an onion skin is far from being the most fascinating sight that you can see through the magic tube.

CHAPTER II

WONDERS OF THE PLANT KINGDOM

WHAT is life?

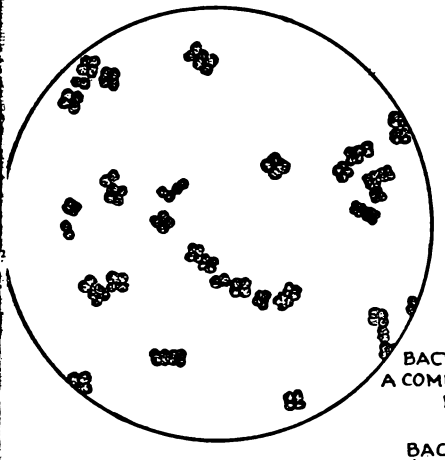
No one has been able to answer that question, and perhaps never will be. But with the aid of the microscope, scientists have been able to form definite ideas about life, and to approach more closely than ever before to the answer to the question that has bothered people ever since the human brain learned to think.

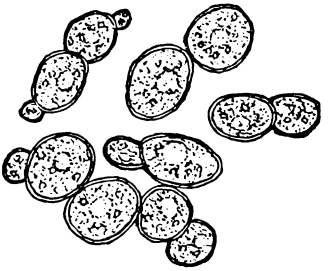
One of the first wonders that you ought to study with your microscope is the unit of life, the cell. All plants and animals are made up of tiny cells, much as a great building is composed of bricks. Living things grow because cells have the power of increasing in size and of dividing to form more cells.

The most important substance in a living organism, whether plant or animal, is protoplasm, the material that, as Huxley said, is the physical basis of life. Protoplasm still remains much of a mystery, for no one has been able to explain how it first acquired the quality called life. You can see protoplasm under your microscope as a more or less cloudy or granulated fluid of which cells are formed. By employing various dyes, you can color protoplasm to make it more prominent.

The cell, as you will see it, consists of a nucleus, a mass of cytoplasm, various other tiny bits of matter

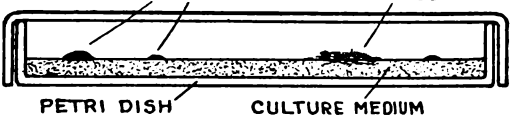
such as plastids that you can see scattered through the cytoplasm, and a thin wall or skin to hold all these things together. Walls of plant cells are made of cellulose, the material you have encountered many times as absorbent cotton, linen, and paper.





YEAST PLANTS
GROWN IN MICRO-GARDEN

BACTERIUM SARCINA LUTEA
A COMMON PLANT FOUND IN
DUST GARDENS



DUST GARDEN,
CROSS SECTION

A plant or animal may be composed of millions of cells; or it may consist of only a single cell. The million-celled individuals are the ones that everyone knows—the oak trees, corn plants, grasses, elephants, dogs, and mosquitoes. Most persons never hear about, much less see, the far greater number of tiny plants and animals that live in the microscopic wonderland that lies beyond the range of ordinary eyes.

With your magic tube, your eyes no longer are ordinary. They have been given new power. To test that power, your next Microland excursion will be in search of one-celled wonders that only the privileged few who possess microscopes can see. You are going to explore a micro-garden.

You cannot go out into any field and find a micro-garden waiting to be magnified. You have to make it, a task that is very simple. For one form of garden, add a yeast tablet or a piece of yeast cake the size of a pea to a tumbler half full of water in which has been dissolved a teaspoonful or two of molasses. Set this in a warm place for a few hours. Then, with a dissecting needle or dropper, transfer to a microscope slide a drop taken from the cloudy part of the mixture. Place a clean cover glass over it and look at it through your microscope.

You see a one-celled world. Each little, rounded particle is a yeast plant. At a magnification of 300 or so diameters, you can make out something of the interior construction of these plants. A little iodine or other stain will help.

What's this? Here is a plant that looks as though it has two cells! There is a large cell, and a little one sticking out from it like a swollen nose. This will bear watching. Make frequent observations over an extended period, and you will see the nose finally grow larger, and produce a nose of its own. After a while there is a chain of several cells. Then the chain breaks up, and the cells are seen as individual plants once more.

You have witnessed one of the most important things that happen in the plant world: you have seen

a one-celled plant growing into two or more plants. New life being created! That is a process that has been going on ever since the begining of life, millions of years ago. As far as is now known, new life can be produced only from old life.

While the yeast cell was sprouting buds that later became new yeast plants, it was doing a lot of things you could not see with your microscope, but which are so important to human life that they involve millions of dollars and affect the lives of millions of people. The yeast plant was eating sugar and converting it into alcohol, carbon dioxide, and some minor substances. It is this production of alcohol by growing yeast that enables the brewing industry to manufacture alcoholic liquors. The ethyl alcohol in your micro-laboratory was made by yeast plants.

If you let the molasses supply of the yeast plants become exhausted, some of the cells will go to sleep, converting themselves into spores which remain inactive inside a thick wall. It is these spores that float about in the air and settle on overripe fruits where they start growing again; or some of the spores may alight on ripened grapes, later to become submerged in grape juice, where they grow and produce wine. The yeast family is a small one in the plant world, only about half a hundred species being known; but it is a highly important and valuable family.

There is another kind of micro-garden that you will enjoy making. In it you can grow dust plants.

First prepare the soil by boiling a quarter-pound of beefsteak in a cupful of water for 15 minutes, adding about ⅛ teaspoonful of baking soda, and 3 tablespoonsful of granular gelatin or agar agar previously

moistened with water, and boiling for ten more minutes, or until all of the gelatin or agar is melted. Filter this through wet flannel into a wide-mouthed bottle such as a ½-pint milk container, and set aside until the next day.

Your garden plot is a petri dish, or a dessert dish, covered by a glass plate. Place the dish, with cover in place, in a cold oven and gradually raise the temperature until a piece of white paper placed in the oven will scorch. Leave at this temperature for 30 minutes. This is to kill any bacteria or other dust plants that may be on the dish. Another way of sterilizing it is to heat it in a steam bath for an hour or two.

Set the bottle of beef-gelatin in cold water that reaches almost to the top, put a cloth beneath it to separate the bottle from the container, and bring the water to a boil, continuing for 15 or 20 minutes. This is to kill any tiny plants that may have managed to get into the bottle. Now carefully lift the cover of the petri, or dessert dish, and pour in enough of the soil to form a thin layer. The dish and culture medium should be cool enough to handle comfortably. When the soil has hardened, your dust garden is ready to plant.

Simply place it in a room, remove the cover, and let the dust of the air fall upon it for 15 minutes. If the room has just been swept with a broom, leave the dish open only two or three minutes. During that time, you will capture a number of tiny plants. Set the dish in a warm place, and wait a day or two for results.

The results will appear in the form of spots on the soil surface. In a few days you will distinguish a variety of spots. Some will be gray, dark brown, or

black. Close examination, perhaps with a hand magnifier, will reveal that these are tiny forests of molds or fungi. You probably have seen them on moist stale bread and cooked red beets that have been kept too long. Probably the most numerous dots in your petri dish garden will be shiny, and colored white, gray, or yellow. These are colonies of bacteria, tiny one-celled plants that are even more important than yeasts. Each shiny spot shows where a single germ fell while the dish was uncovered. That microbe grew until there were thousands of similar plants, enough for you to see collectively.

Perhaps some of the bacteria are large enough for you to see with your microscope. With a needle, carefully lift a tiny bit from one of the yellow spots, and place it on a clean slide, spreading it out in a thin smear. Drop some alcohol on it, let the excess drain off and, with the slide lying on a watch glass or other support, touch a match to the alcohol film still covering the bacteria. It will burn off quickly, "fixing" the bacteria.

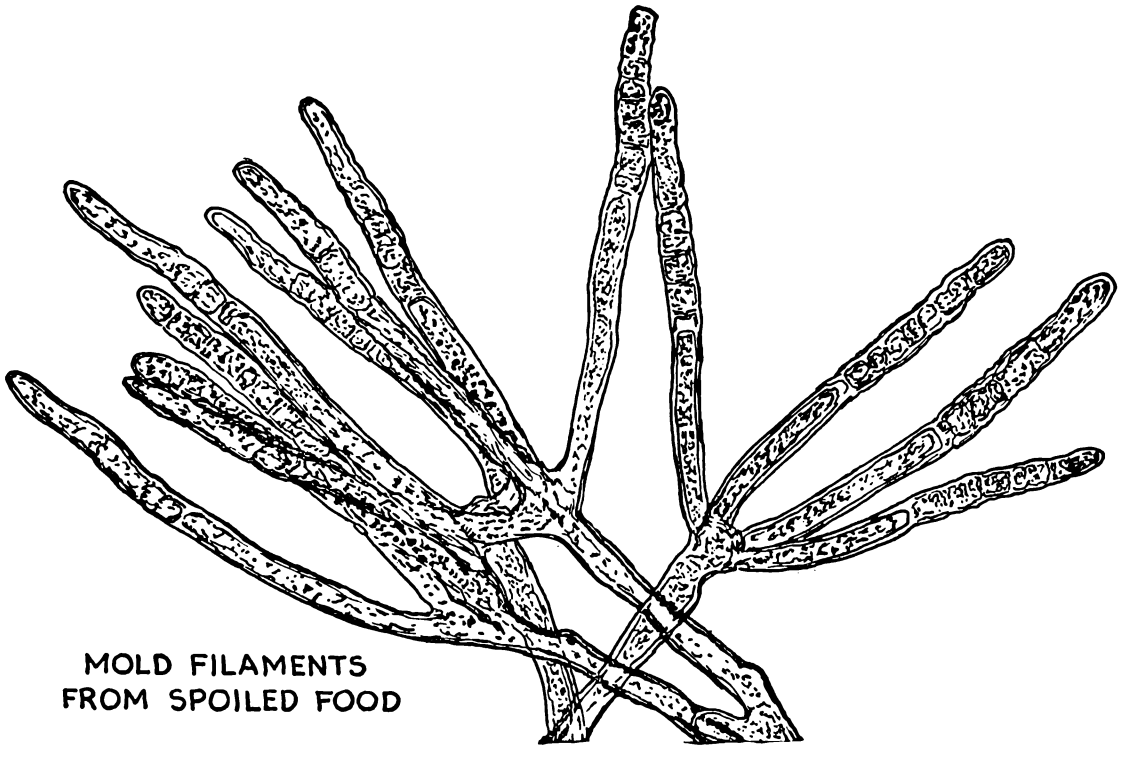
Here is a word of caution: It is probable that the germs you are growing in your dust garden are harmless, but to play safe, do not let any of them get on your hands. Sterilize, in a flame, the dissecting needle you used to pick them up; and when you are through experimenting, put all slides, dishes, and other articles that might have come in contact with the bacteria, in a pan filled with water in which is dissolved a little washing soda. Boil this for two hours, to kill all of the organisms present.

After you have fixed the bacteria on the slide by the alcohol method, drop some water on the smear and add

a stain such as Loeffler's methylene blue solution. Let this remain for a few minutes, then wash off with water and dry the slide over a flame, being careful not to heat it too much. Drop some petrolatum or balsam on the colored film of bacteria, add a cover glass, and you are ready to inspect them with your microscope. If your instrument magnifies from 300 to 500 diameters, you ought to be able to see the individual germs, or the small groups in which they sometimes collect. If you have captured Sarcina lutea, a common form of bacterium found in the air, you may be able to distinguish the little groups into which this organism separates, and perhaps see the individual cells. This type of bacteria reproduces by dividing in three directions, and the cells cling together for a while, looking for all the world like tiny packages tied with string.

The molds you grew in your micro-garden probably will prove more interesting than the bacteria because they are larger. An easier way to get a good collection of molds for study is to moisten a piece of bread and let it lie under an overturned dish for a few days. An abundant crop of black mold plants will furnish much fodder for your microscope. The ease with which this mold can be grown indicates that it is present everywhere in the air, at all times.

Carefully transfer some of the white threads that form a spider-weblike mass, together with the tall, slender stalks on which are black balls, to a drop of water on a slide. At 30 diameters, you can clearly see the plant form. At a higher magnification, you can see the structure of one of the black balls, which is a spore sack. The spores produced in this ball float about in the air until they find a piece of moist bread or bit



MOLD FILAMENTS
FROM SPOILED FOOD

of neglected food on which to grow. Petrolatum is an excellent medium for mounting mold-spore cases on a slide.

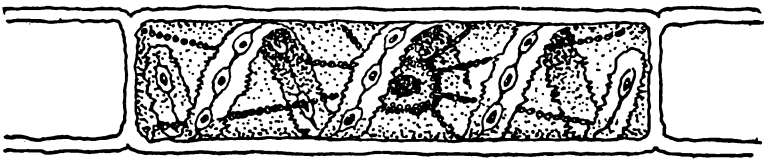
There are numerous other molds that you will find interesting, once you turn your magic lenses on them. Perhaps, during the summer, you will find a dead house fly attached to the window pane, with a grayish or white circle around it. This circle is composed of the white spore balls of Empusa muscorum, a fungus that attacks living insects. The sporangia are shot from the hyphae of this fungus somewhat like a stone from a sling. You can find various molds in decaying food, rotting wood, and almost any other moist place. They are favorite subjects for microscopic study.

Sooner or later every budding naturalist finds a stagnant pool and thereafter thinks that he is in the microscopist's heaven. He discovers, below the surface of the modest little pond, a million wonders—countless mysteries for his microscope to investigate. Only a few of the wonders you will find in such a pool can be mentioned here. For the moment, we will disregard the tiny forms of animal life that you can scoop up with an old tin can or a more professional-looking collecting net.

The Algae, tiny, bright-green plants that you find in ponds and in fish bowls and elsewhere, are unavoidable. There are some 9,000 species known (none of which is of much importance, economically) so you will have no trouble in obtaining specimens. The green Algae occur in a variety of forms. You will find tiny Algae plants equipped with cilia, hairlike tails, that enable them to swim about in the water. Yes, actually swim, although biologists classify them as plants. In

fact, there is some disagreement about some of these tiny bits of life.

Consider Volvox globator: In ponds you may find the water green with tiny little balls which may attain the size of a pinhead. The balls slowly roll over and over and move about in the water. Put one of them under your microscope. At 125 diameters, it appears the size of a golf ball. You can see that it is made up of hundreds of tiny units or cells, and that, projecting out all over the surface, are the waving cilia that enable the ball to move in the water.



SPIROGYRA

Authorities differ regarding this microscopic object. Some textbooks of botany list Volvox among the Algae plants, classifying it as "a remarkable plant." In some textbooks of zoology you will find Volvox described as a "plantlike flagellate"!

A Microland wonder that gets its name in both botany and zoology textbooks, because authorities do not yet know whether it is a plant or an animal, surely is worth searching for.

Often, on the water of ponds, you will see large masses of Spirogyra, long, thread-like Algae that are slippery to the touch. Oxygen produced by the plants appears as bubbles throughout the green mass. You will find Spirogyra worth hours of study, the spiral

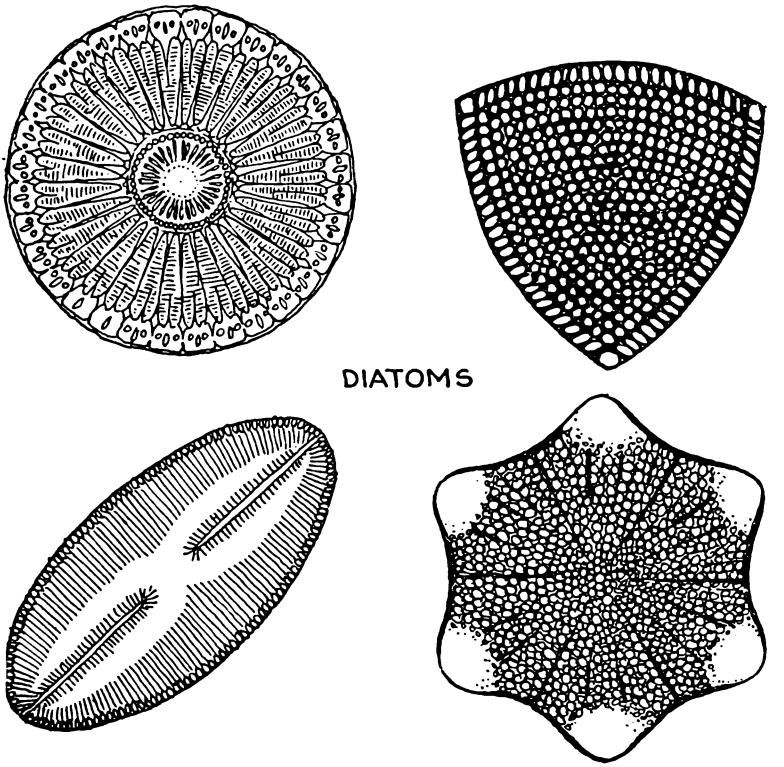
structure of the cells placed end to end to form threads appearing clearly at moderate magnification.

The best way to examine Algae with a microscope is to mount them on a slide in water. This applies to other forms of water life, both plant and animal. Perhaps you will have trouble in finding the one-celled plant forms in a sample of pond water. A method suggested by Behrens may be of help. Place some of the water in a watch glass that rests on a paper colored half white and half black. Against the black background lighter colored organisms are visible under a hand lens; against the white background the darker ones can be seen.

Where do you think you will find the Plant Kingdom's main storehouse of treasure jewels? It is in the most unattractive of places, the slimy ooze on the bottom of a pond! Dip up some of this, take it home and spread a thin layer on a slide. If you have been lucky, you will find, here and there, little jewels whose beauty will amaze you. These are Diatoms. You probably collected both the silica skeletons of Diatoms and the living plants themselves. No two will be exactly alike. Some may be round, some triangular, some five-sided, and others long and shaped somewhat like the letter S. They are marked with fine ridges, pits or pores. So fine are these markings that certain Diatoms are used to test the quality of microscope objectives.

A Diatom is a one-celled plant—member of one of the Algae groups—having a skeleton composed of silica, the same material as sand. Therefore, Diatom skeletons exist for millions of years, retaining all of their natural beauty. Perhaps you brushed your teeth with some of these million-year-old plant skeletons

this morning, for they are excellent polishing agents and are used in certain toothpastes and silver polishes. They also are used as absorbents in the manufacture of



DIATOMS

dynamite and nitroglycerin. If you discover a tooth-paste that contains Diatoms, place a quantity of it in water, let the solid material settle to the bottom, and pour off the rest. Then place the settlings on a slide.

Perhaps you will capture some living Diatoms. You

can study them in a hanging drop. Some of them can swim about in the water, somewhat like animals. You will be so spellbound by their beauty that you will want to preserve some of them. The skeleton, which retains the markings, is the part you can mount. Mix some concentrated nitric or hydrochloric acid with an equal part of water and place the Diatoms in it. Boil the mixture for an hour, then dilute with water, and set aside for several minutes until all of the Diatom skeletons have settled to the bottom. Carefully pour off the water, add fresh water, let settle again, and pour off. Then add water in which some carbonate of soda (washing soda) has been dissolved, and boil for another hour. Wash as before, and finally transfer some of the sludge to a microscope slide and let it dry thoroughly. Then carefully apply a drop of balsam previously thinned with xylol, and affix a thin cover glass. Make as many slides as convenient, for you will find these tiny skeletons always interesting and always different.

There are other one-celled microscopic plants that look very much like Diatoms but do not have silica skeletons that can be preserved. They are the Desmids, beautiful cellulose-walled plants that float about in fresh water or cling to the sides and bottoms of ponds. A characteristic of Desmids is that they are formed of two symmetrical halves, each resembling the mirror image of the other. Usually there is a narrow place between the halves, in which the nucleus of the cell is found. The surfaces of Desmids may be covered with spines, knobs, or other markings. The thousand or so kinds of Desmids known have no particular value, other than their being, like the Diatoms, sources of

inspiration for artists and designers. They are best observed in water under a cover glass, or with a hanging-drop arrangement.

Do not neglect the everyday plants, such as the lily and radish and the walnut tree, in your search for microscopic wonders of the plant world. They contain hidden details no less interesting than the stagnant pond.

The leaves of plants contain a mystery that never has been solved. In them are cells that are able to convert sunlight and carbon dioxide and water into sugar and starch and oxygen. This process is called photosynthesis. With your microscope, you can study the different kinds of cells that make up the plant leaves, and see the green chlorophyll that is the chief actor in photosynthesis. The hairs that grow on leaves and stems make interesting microscope material. You can peel the epidermis from some leaves with ease. You will find it always interesting. To turn a microscope directly on a leaf does not give much satisfaction. You may see some of the pores or "stomata" on the underside, or some of the projecting hairs; but you are missing the most interesting part, the internal structure. You will have to slice a leaf into a thin section which, properly mounted, shows under the microscope several remarkable things.

On the upper and lower surfaces are orderly rows of cells, forming the epidermis or skin—the part you can peel off some leaves. Between the epidermal layers are cells containing green chlorophyll. You are looking, in these cells, at the plant's food factory. Scattered among the green cells are groups of colorless, compact cells forming the veins. Then here and there

near the lower surface, are air sacs and pores through which the leaf breathes. You will find the green cells worthy of special study. The grains containing the green chlorophyll are most conspicuous. The cells also contain protoplasmic material that is pressed against the cell walls by the sap, which is water having sugar and other substances in solution.

Examine the veins. You can distinguish three kinds of cells. First, the outer group forming the bundle-sheath. These cells have thick walls. Second, the sieve tubes, small cells with thin walls, lying in a bundle toward the bottom of the vein. Finally, next to the sieve tubes, near the top surface of the leaf, are larger, angular cells in which there is no protoplasm. These are the water-carriers, the traechids and ducts. When examined in longitudinal instead of cross section, these cells show various surface markings, such as spirals.

With a razor, slice the woody stem of a plant into a thin section and look at it under the microscope. You will observe that, in many respects, it is constructed like the veins of the leaf—that, for instance, there are cells which specialize in carrying water, and which appear larger than most of the others. The Dutchman's Pipe plant, commonly used for shading porches and decorating arbors, is an excellent plant to study for stem structure.

Although the stem of this plant in cross section is, in its natural state, one of the most beautiful of garden treasures, you can enhance its natural beauty by a simple staining operation. After cutting the stem section, place it in a few drops of eosin stain on a glass slide. Let it remain several minutes. Then remove from the stain with tweezers, rinse well in clear water, and

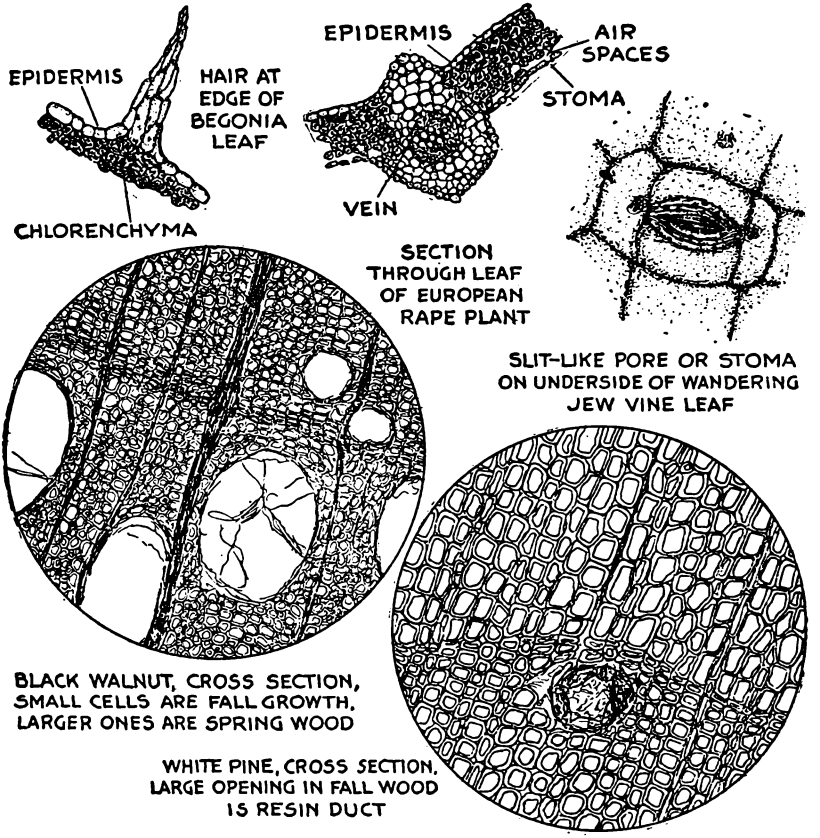
place in Loeffler's methylene blue stain for a minute or two. Rinse again, and mount in water under a cover glass.

Adjust the microscope for a magnification of about 50 diameters and look at the stem. What a breath-taking sight! To the natural beauty of the cell network has been added the magic of artificial color. Generally the thick-walled, woody cells take up the methylene blue very readily, while other parts of the stem are stained differently. Then, to the artificial colors is added the natural green of the chlorophyll in the cortex cells. All the colors are blended delicately, producing an effect that the most skillful artist would have difficulty in duplicating.

Lumber is essentially nothing but the dried stems of trees. Therefore, if you slice a thin section from walnut or pine or oak that has been softened in water, cutting across the grain, you will observe many interesting things. You will see, in white pine, various enlarged cells that make up the resin ducts. You will notice that the other cells become progressively smaller as you move from one side of the specimen to the other, and that they then become suddenly larger. The lines between groups of the large and small cells mark the boundaries of yearly growth. The large cells grew in the spring and summer; the smaller ones, however, grew in the fall.

Another interesting part of a plant to investigate is its roots. You will discover that each root tip is equipped with a tough sheath that pushes through the soil, like a spearhead, making way for the less sturdy growing point that can be seen as a yellow spot lying directly behind the sheath. Then there is the growing

zone, and after it the hair zone, each easily distinguished.



You will find fascination in every flower bud, in every fully developed blossom. From the bud you can prepare thin sections that will reveal new wonders. The flower provides delicate reproductive organs, and

pollen grains which assume a variety of interesting forms. Seeds, particularly small ones whose details you normally cannot see, form a distinct Microland attraction. You will find the various kinds of vegetable starches entertaining. Compare the grain forms of starch from a bean with potato and tapioca starch.

Microscopic jewels occur in the larger plants, just as they do in the bottoms of ponds. However, they are different because they are merely tiny specks in the plant structure and not its entire skeleton. These jewels are plant crystals. They are found in cells of plants, frequently very beautiful in form. The chief materials from which they are made are carbonate and oxalate of lime. So far as is known, such crystals are of no use to a plant, being by-products of the plant's activities. They appear in the cells of begonia, onion, and other plants.

After you have spent several evenings roaming through the plant kingdom and seeing wonders you never imagined in your wildest dreams, you will begin to feel, growing upon you, a new appreciation of Nature. You will feel a little superior, too, and with good reason. It is not everybody who can see, in the backyard garden, things more fascinating and more beautiful than the choicest rose growing there; it is only the owner of a microscope who is privileged to glimpse the real wonders of the plant world. And as if that were not enough, beyond lie the fascinating realms of the Animal Kingdom.

No wonder the hobby of microscopy is so engrossing!

CHAPTER III

LIVING WONDERS IN WATER

WITH the microscope you can expand a drop of water until it is the size of a room, and then gaze in awe at the ferocious, and often beautiful, creatures it contains, much as if you were in a zoo. But what a zoo! Instead of snakes there are strange-looking worms with pins sticking out of their skins. You can see no octopus, but there is instead the fascinating Hydra. No sloth hangs from a limb in a cage, but there is a sluggish Amoeba that puts out a foot of jelly and then flows into it.

Visit a different drop of stagnant water, and you find yourself in an entirely new zoo. It would take you a long time to see all of the microscopic animals that could be encompassed in a water drop. Likewise, it would take a lot more paper to tell about all of them than there is at my disposal. Only a few of the tiny creatures can be mentioned; you must discover the scores of others for yourself, and identify them by referring to some standard zoology book.

Away down at the bottom of the scale of life is a little speck of animated jelly that has become world-famous because it represents about the nearest approach to nothing of anything that is alive and able to move about. This bit of protoplasm is the Amoeba. It is an entertaining creature to watch, as it crawls

slowly across the field of your microscope; and it is instructive, too, for you can learn from it many of the secrets of the all-important cell.

Where, you ask, can you capture an Amoeba so that you can put it under your lens? Visit a shaded pond and get some of the ooze that lies on the bottom or clings to the underside of a water lily leaf; also collect a mass of pond weeds. In gathering such material, you can use an old tomato can on a stick or a bottle tied to a string, but you will find the collecting net described elsewhere in this book to be more satisfactory.

Take your collected material home and put it into glass jars partly filled with some of the pond water. Place the weeds in a container by themselves, and in a few days a scum will form on the surface of the water. This scum may contain as many Amoebas as you need. The other material from the pond bottom and the lily leaves perhaps will provide a great many, too. But do not be discouraged if you find none, for the Amoeba sometimes is difficult to capture, and even harder to culture. Keep the jars in a warm place, near a window but not in direct sunlight. Even if you discover no Amoeba, you will find that you have dozens of other little animals, each worth an evening of study with your microscope.

While you are in the business of producing specimens, put a handful of dried weeds or hay into another jar and pour water over it. In a week or so you can collect an amazing variety of tiny living forms from it.

The Amoeba is hardly more than a bit of animated jelly. It is the most formless, softest bit of life you are likely to find. Still, in that speck of jellylike proto-

plasm are signs of sense development. The Amoeba seems to know in which direction to look for food, and to be able to select whatever it wants. It draws itself up into a ball when disturbed, although it has no nerves.

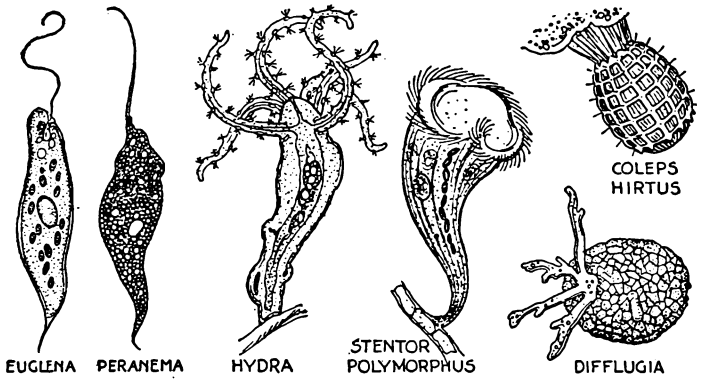
The Amoeba travels by projecting outward a slender, blunt "pseudopod" or false foot, and then flowing into it. The protoplasm that makes up the cell is colorless, but often contains particles that render it visible. Thus, Amoeba proteus, the form you are most likely to encounter, seems to be filled with dark, crystal-like granules that suggest wet, black sand. These grains flow about inside the cell in a manner you will not forget easily, once you have seen the action. When the Amoeba finds a piece of food, it simply flows about it until the tidbit is completely surrounded, and then proceeds to digest it. Any part of the mass of protoplasm can do the work of a stomach.

The Amoeba has among its relatives the Difflugia, which is a more beautiful and interesting object. It builds, out of tiny grains of sand, remarkable little shells in which to live. The sand grains are fitted together evenly, like the work of a mosaic artist, and cemented with chitin. There are several kinds of Difflugias. Some build shells shaped like pears, others like caps or helmets.

You may be lucky enough to capture, on a strand of Spirogyra, a pear-shaped Difflugia. The sand-grain shell is open at the small end. If you watch carefully, you may see, moving out from this opening, long, slender, colorless strands of protoplasm with which the animal snares its meals. When outside of its sand-grain shell, the animal resembles an Amoeba. Some-

times, instead of sand grains, the shell is constructed of Diatom skeletons, making it a microscopic jeweled palace.

Most of the Amoeba's close relatives can move about where they please, but there is a particularly beautiful form, called Clathrulina elegans, that is anchored by a stem. It resembles a hollow sphere, pierced

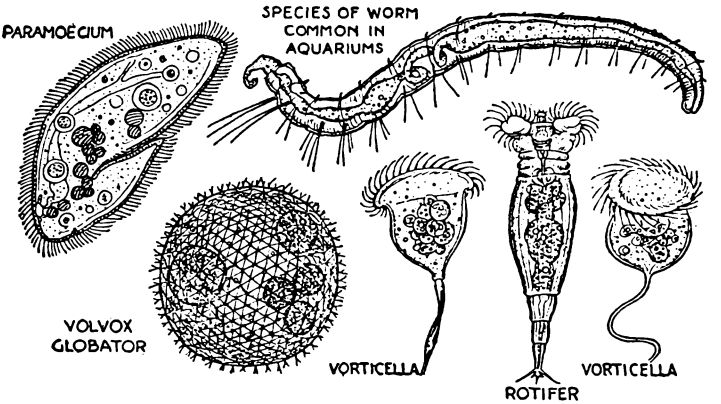


by many holes, attached to a slender stalk. Inside the sphere is the jellylike animal that sends out, through the holes, threadlike arms in search of food.

In your Amoeba jars you may find Euglena, a little one-celled animal that is wide in the middle, pointed at one end and equipped with a long, threadlike flagellum that projects from a "mouth" at the other. Near the flagellum you may detect the "stigma," a spot that looks like an eye, and is supposed to be light-sensitive.

Paramoecium is a common animal that frequently occurs in Amoeba cultures. You can recognize it by its

resemblance to a slipper, a characteristic which led to its being called the "slipper animalcule." The Paramoecium has its mouth near its middle, and is covered with hairlike cilia. You may capture a few of these animals in a garden pool, but a hay infusion is a better source. Against a suitable background, a Paramoecium can be seen with the naked eye.



In the hay water you ought to encounter a number of interesting animals that, in some ways, resemble plants. There is, for instance, Vorticella, which looks somewhat like a bell or lily blossom on a coilspring stalk. The animal has a cilia-fringed mouth at the larger end. With these cilia, it beats the water, creating currents that carry food into its gullet. Extending from the small end of the cell to some convenient anchorage is the stalk. If something happens to frighten the animal while it is feeding, the stalk coils up like a released spring, and yanks the Vorticella down to safety quicker than your eye can follow. There are a

number of other protozoa forms that employ anchoring threads.

You will, undoubtedly, encounter a remarkable and fair-sized creature who boasts the name of Stentor polymorphus. When "Poly" is feeding, he looks somewhat like a trumpet-shaped horn attached at the small end to a stationary object. If you get him under a cover glass, he may cling either to the glass or the slide. The body of the animal is covered with fine cilia, while around the large, or mouth end, is a row of larger hairs that wave and create food-bearing currents. You can see the food entering the greenish body and digesting. Stentor polymorphus can fold up its single foot and swim about freely in water.

A common inhabitant of ponds and ditches is a small animal, sometimes just visible to the naked eye, that has the peculiar property of being able to sprout new heads and other body parts to replace lost ones. This is the Hydra. It has a cylindrical body that is attached at one end to a submerged plant. On the other end are a number of long, slender arms, causing it to resemble somewhat an octopus. With these arms the Hydra reaches out and captures microscopic worms and other bits of food. In captivity in one of your aquarium-zoos, it even may eat small bits of meat. The Hydra's arms are equipped with stinging cells, which explode and shoot poisonous, barbed tubes into its prey. Surely a remarkable little creature!

As far back as 1739 a Dutch naturalist named Trembley told how he had cut Hydras in two, and then watched each half sprout new organs to replace those lost, the net result being two Hydras where there had been but one. When left to its own resources, one

Hydra can become two by a budding process, the new animal sprouting out of the side of the older one.

The sea-dragon of Microland is a fresh-water worm called Nais. The leaves of plants that have been growing for some time in fish bowls, particularly tropical aquariums, generally provide it in abundance. This worm is long enough to be seen as a thin, white line with the naked eye. Under the microscope it is an interesting creature indeed. You can see all of its inside organs, watch its food enter and travel through the alimentary canal, and watch the movements of the body fluid that carry the floating organs one way or the other. The worm has red blood. Nais owes much of its ferocious appearance to the sharp-pointed spines that extend outward in clusters from both sides of its body, and to the group of spines near its head. You will find this worm a highly active animal, and you may have some difficulty keeping it in the microscope field.

Perhaps one of the first microscopic animals that will grip your attention is one of the more common Rotifers. Although in some ways it resembles Stentor polymorphus and other low forms, the Rotifer is a much more complex organism. It can swim about in the water, or travel by grabbing the surface with first one end and then the other. When feeding, it attaches itself to some solid object by a single, jointed foot, and then opens, from the mouth end, two disks covered with cilia. By waving these cilia rapidly, it fans a current of food-laden water into its mouth. This Rotifer is to be found in almost every ditch or pond. In fact, you can hardly escape it, if you collect any kind of microscopic water life.

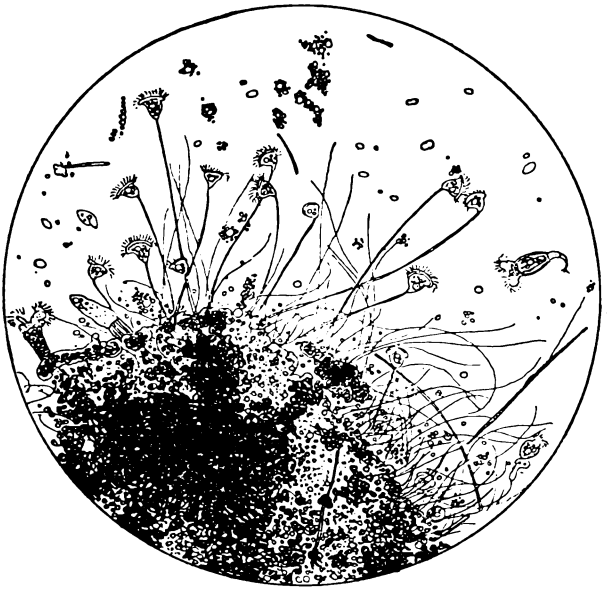
A lively little creature that inhabits ponds, and that

is raised in large quantities for feeding to tropical fish, is Daphnia or the water flea. It is fairly large for a microscope object, so much so in fact that you may not be able to see it all at once unless you have a fairly low power objective. Daphnia is related to shrimps and crabs.

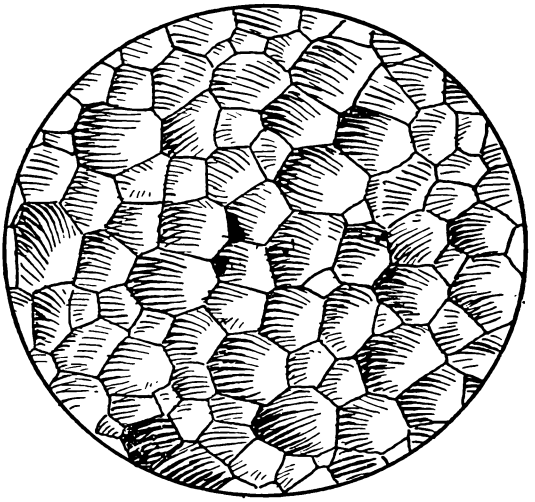
The first impression you get upon looking at this creature is one of intensive action. Everything about it seems to be moving, like the parts of a printing press. Projecting from the head end are two long antennae that end in several feathery branches. Somewhat forward of the points where these antennae join the body is a dark spot that sometimes vibrates rapidly, as if in step with the other motions. This is the eye. At the lower part of the body, beneath the shell, are the rapidly beating legs that, by creating currents in the water, carry food to the Daphnia's mouth and oxygen to its blood. At the top of the body, toward the front end, is the heart, whose expansions and contractions, as it sends its blood on its way, are fascinating to watch.

Behind the heart you may see several dark, round objects enclosed in a little pocket. These are the eggs, which the mother carries around with her until they are hatched. Perhaps you can capture a Daphnia whose eggs are almost ready to break open. Then you can see, moving about inside the eggs, the young water fleas.

To observe Daphnia and other fairly large, living creatures on the ordinary microscope slide may be a bit difficult. To make it easy, procure a washer about $\frac{1}{16}$ inch thick and of the proper diameter to support a cover glass, and cement it to the slide with shellac or



COLONIAL PROTOZOA. VORTICELLAE



CRYSTALLINE LAYER OF SEA SHELL

balsam. Into the well formed by the washer, you can introduce a water flea or a whole circus of water animals. If you do not want your specimens to die, remove the cover glass every few minutes and let air come in contact with the water.

In every microscopist's laboratory there should be an aquarium reserved for snails. In a lake or pond, you can find the active little pond snail. From a dealer in goldfish, you can buy various other kinds. After the snails have been in your aquarium for a while, you will discover little jellylike clusters of eggs sticking to the glass or to leaves of plants. The eggs themselves are interesting material for study with low powers, but they are ten times as fascinating if you observe them when they are almost ready to hatch. You can watch the antics of each tiny baby snail as it twists and turns about inside the egg.

Perhaps the most interesting part of an adult snail is its tongue. It is built like a sanding belt or wood rasp. As the snail crawls over the glass or plants, it moves its ribbonlike tongue rapidly over the surface, scouring off and into its mouth any food that may be clinging there. You can see the tracks left by these rasping tongues on any aquarium that has a layer of green scum on the glass.

To examine the toothed tongue or "lingual ribbon," you first must separate it from the snail's body. A quick way of doing this is to drop a pond snail, without its shell, into a test tube partly filled with a solution of caustic soda or potash (sodium or potassium hydroxide or ordinary lye), and heat or boil until all of the soft body parts have disappeared. Then let it cool, and carefully pour off nearly all of the liquid.

The ribbon, which is difficult to see because it is nearly transparent, will be on the bottom. Therefore, examine the last few drops of the liquid with a hand lens, being watchful for a curled, whitish object. When you find the tongue, you will agree that it is worth the trouble required to prepare it. Use your highest magnifications for examining the teeth.

Because the pond snail multiplies rapidly and will soon eat up all of the plants in a small aquarium, you must keep it to itself. Feed it lettuce if you run out of natural plants. Other jars in which you are raising specimens should be inspected every day and all snails and eggs removed, until there is no further danger of their developing. If you do not do this, the snails will destroy the vegetation upon which the microscopic animals depend for sustenance.

Fish—tropicals, goldfish, or the kinds you catch in lakes and streams—will provide an abundance of wonders for you to study. This is true of the scales in particular. By removing scales from the back, abdomen, and from the lateral line that extends along each side, you will discover that not all scales on the same fish are alike.

It may surprise you to learn that some fish scales look as if they were installed backwards. This is true of the perch. One part of a perch scale is studded with blunt-pointed crystalline spines that are arranged in overlapping rows, while the remainder is relatively smooth, having an undulating outline. You would guess, if you did not see the scale removed, that the spiny part was anchored in the skin, while the smoother portion projected. However, the reverse is true, so that the perch, as well as other fish having

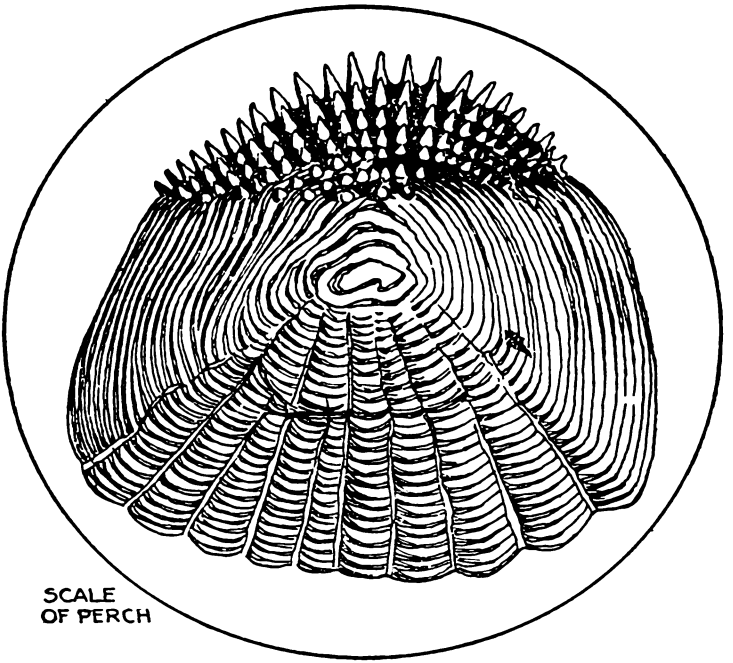
scales of the "ctenoid" (comblike) type really is covered with hundreds of little spines. Other scale forms are the "ganoid" and the "cycloid," the last-named being smooth-edged, while the ganoid are laid edge to edge.

You will find that the entire ctenoid or cycloid scale is marked by concentric rings, which look as if they were edges of thin, overlapping plates; and that there usually are radiating lines extending to the edges of the scale. Much of this area is relatively clear and colorless, but on many scales there is a patch of color. Under the microscope you find that this patch is a wonderland in itself.

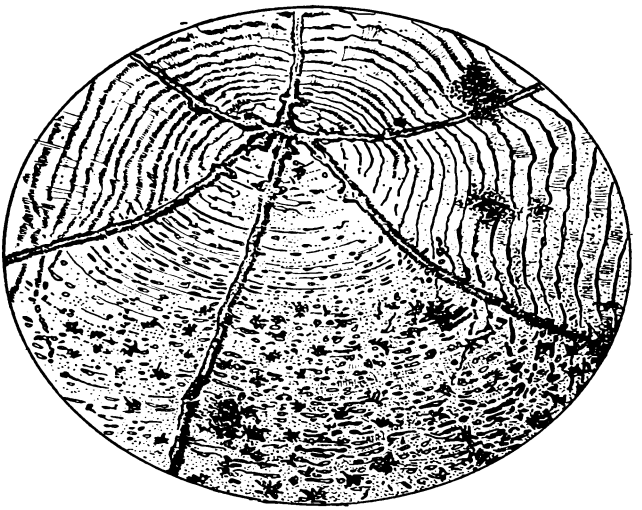
The scale of a brightly colored tropical fish, such as a rosy barb or a guppi, is particularly desirable when you are exploring this color patch. The barb scale, for instance, exhibits little, irregular color patches that resemble in form a many-footed Amoeba. These are pigmented cells that contribute to the general color scheme.

But it is not color alone that makes the fancy fishes so beautiful. Much of the credit belongs to the iridescent, pearl-like luster that is characteristic of fish in general. What causes this luster? To find out, you will have to scrape the pearly patch from a fish scale and place it in a drop of water on a slide. You can do this with a pair of dissecting needles. Tear the bit of membrane to pieces, until the water drop glistens all over with hundreds of points of light.

Place a cover glass over the drop, and examine it. You may have some difficulty getting the illumination arranged, and may have to employ a dark-field arrangement, before you can see the thin, flat, narrow



SCALE
OF PERCH



SCALE
OF
ROSY
BARB

plates, or crystals of guanin, which are responsible for the pearly luster. Each one of these plates acts as a tiny mirror that reflects a beam of light. When suspended in a liquid, they are dancing about constantly, reflecting a thousand points of light in a thousand different directions.

It is these reflecting plates that are extracted from the scales of certain fishes to make the fish-scale essence of commerce. They are used to coat the insides of glass beads to make artificial pearls; they are mixed with cellulose products to form the pearly backs of toilet mirrors and brushes; they even are mixed with automobile lacquers to produce an unusually beautiful finish.

If you live near the seashore, you can enjoy a watery zoo that is entirely different from that which the fresh-water pond has to offer. There are hundreds of microscopic creatures of the sea that are worthy of your acquaintance. From a strand of floating seaweed, you may obtain enough to keep you busy with your microscope for a week.

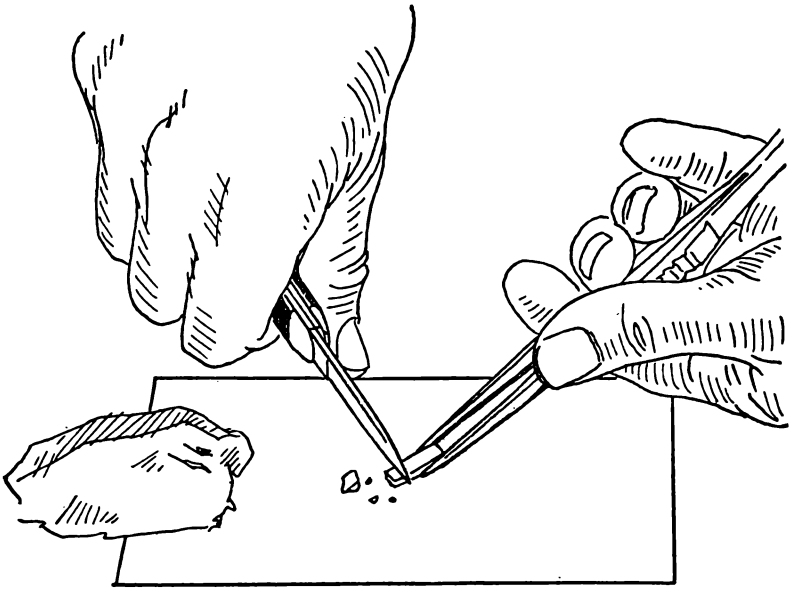
Even if you do not live near the sea, you can enjoy some of its wonders. At any store you can buy cuttlefish bone for the canary, and from someone you know you surely can borrow some sea shells that will astonish you with their beauty. Do not give the cuttlefish shell to the canary. Instead, cut a little cube from it and examine it with your microscope.

You see a crystal palace, far more beautiful than any creation of luxury-mad kings. The material, you observe, is divided into layers, and between the layers are winding ribbons of glasslike material, a thousand times more delicate than any ribbon you ever saw.

The cuttle shell is made of limestone. Place it in water and it will float.

"But, limestone is a heavy material!" you exclaim.

True, but the structure of the cuttle shell is respon-



PREPARING CUTTLE FISH BONE

sible for its buoyancy. The system of parallel floors, separated by thin ribbons or plates, produces great strength combined with great lightness, a feature of utmost importance to the cuttlefish, which carried the shell *inside* its skin. The buoyant shell acted as a float and assisted the fish in swimming; and at the same time it gave strength to its body. The shell is removed

easily from a cuttlefish by cutting open the flesh that encloses it.

Select, for your next microscopic venture, a sea shell that has a pearly lining and an edge through which you can see light. Certain shells that look as if they were covered with thin amber or horn are excellent.

Arrange the lighting for an opaque object, and focus on a bit of the mother-of-pearl lining. When everything is just right, you will be able to see many fine, wavy, parallel lines covering the surface. They look, when properly illuminated, like the edges of thin plates stacked one on the other, or like folds in a single sheet of thin material. It is these lines, interfering with the light that strikes them, that produce the pearly sheen. A genuine spherical pearl, the kind that costs a small fortune, exhibits similar structure.

You can prove that these lines are surface markings by a simple experiment. Pour over a clean mother-of-pearl surface, a few drops of collodion, airplane wing dope, or clear lacquer. Let it spread out in a thin layer and dry. Then carefully lift one edge and strip it off, transferring it to a slide. Under the microscope you will see the same fine lines you observed on the pearly surface. You can mount this pearl "fingerprint" in balsam on a slide and keep it permanently. Because of its transparency, you will find it somewhat difficult to illuminate properly. Perhaps by staining it or using colored lacquer, you can improve the appearance.

It is difficult to say which is the more beautiful, the mother-of-pearl nacre of the shell or the crystalline layer you will examine next. Find a place along the edge of the shell where the outer layer extends beyond

the inner and is nearly transparent. Examine it at low power. You will find that it is made of many tiny prisms, like a beautiful mosaic pavement. The prisms frequently are six-sided, although the sides are not uniform in length. Strikingly beautiful color combinations often occur. Examine a broken edge, and you will see that the prisms are arranged side by side to form the shell layer, so that you really see their ends when you look at the shell surface. Place a piece of the shell in diluted hydrochloric acid. The violent bubbling indicates that the acid is acting on the limestone that forms the prisms, and is producing carbon dioxide gas. When the bubbling has ceased, wash the piece—handling it carefully so as not to damage it—and again look at it with your microscope. You see the same structure as before, the same prisms arranged side by side. Now touch the piece with a dissecting needle at the point on which your lens is focused. Instantly the mosaic pavement collapses into a shapeless mass. Thus you have determined that the crystalline layer of a shell is composed of crystals of carbonate of lime protected by a thin, horny material. This layer of material is the periostracum whose purpose is to protect the limestone crystals from carbonic acid that may be in the water.

If you want to prepare a permanent specimen of shell, you can mount a piece dry on a slide. The shell of the ordinary mussel exhibits the mother-of-pearl and the crystalline structures.

CHAPTER IV

WONDERS YOU CANNOT ESCAPE

NO matter where you go in Microland, you cannot escape for long some of the most interesting wonders that you will find in that magic realm. Those wonders are the insects and the amazing tools with which many of them are equipped.

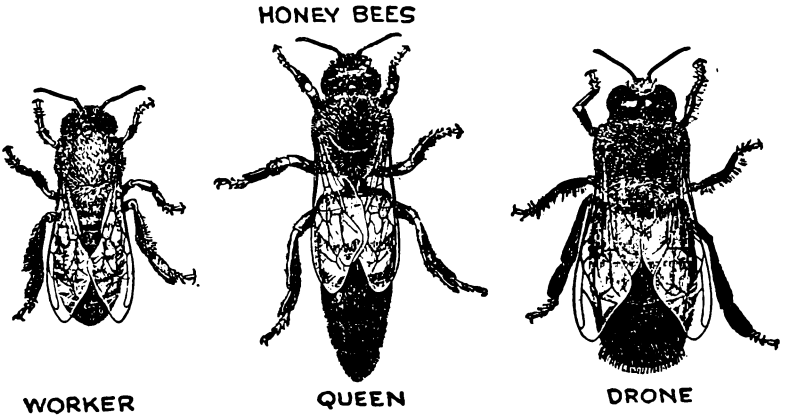
You will discover that insects are in some respects better fitted than the higher animals to overcome the difficulties of life. For one thing, their skeletons are on the outside where, in addition to stiffening the body, they provide protection for the delicate organs within. That is just one of the reasons why insects form the most dangerous army that we, intelligent humans, have to fight.

Here is a piece of amber from the shores of the Baltic Sea. It looks like a piece of resin. In fact, it is resin that was produced by a tree millions of years ago, and which since has become fossilized. Embedded in the amber are several gnats, a few ants and an insect that looks like a beetle. These are not very distinct because the amber has not been polished. If the insects were extracted, microscope slides might be made from them. Slides millions of years old! What treasures for the microscopic side-show!

Upon examining the insects, you might find that they are exactly like ants and gnats and beetles that

can be seen today, flying or crawling about. The insects reached their present state of development ages ago. Where dinosaurs grew cumbersome and died, the members of the six-legged world thrived, surviving famine and drought and every other kind of catastrophe that Nature imposed upon them. Perhaps the insect race will outlive the human race that, in comparison, is very young.

Not all insects are enemies. The honey bee, for example, is really a helper of mankind because it pro-



duces a popular food and assists in the fertilizing of plant blossoms. It is only when you are stung by a bee that you can regard this interesting insect as an enemy. Even then, if you are wise, you will pull the bee's sting from your skin and put it under your microscope. Then, after studying its marvelous mechanism, you will feel like thanking the unfortunate insect. At most, you get only a swollen neck, whereas the bee, in all

probability, loses its life because its sting, poison sac, and part of its intestinal tract are pulled out when you hastily brush it away.

If you study the honey bee, the legs, eyes, antennae, and internal organs as well as the sting, you will learn much about all insects. A worker bee that you pick up dead at the hive, or that you capture and sacrifice in the interests of science, is a wonderland in itself. You will find that it is equipped with a variety of appliances that you heretofore thought were the inventions of human engineers. The bee has pincers, brushes, combs, surgical lances, a poison factory, hooks, baskets, and other things that were perfected ages before your ancestors thought of such things.

Because you probably think of the bee's sting first whenever you see one of the honey makers buzzing around a flower, you might as well begin with that part of its anatomy. The sting, as you know, is situated at the rear end of the abdomen. Incidentally, a bee's body is divided into three easily recognized parts, the head, the thorax or middle part, and the abdomen.

Hold the body of a worker bee in your fingers or heavy-jawed tweezers and find the two sting feelers that project from the abdomen. These are two blunt-pointed objects that the bee uses in finding a place to insert her sting. Only workers and queens, both females, have stings. The male drones have none. With the tweezers, manipulate the rear segment of the abdomen at the point where the feelers are located, until you force out the slender, sharp sting. You can see it with your unaided eyes. When you grasp it with tweezers, you will find that it is hard and slippery, so that you will have difficulty in holding it. Pull it

from the body. The chances are that you will obtain also the little sac in which the bee stores its poison, together with the threadlike poison-gland ducts.

Under a low power of your microscope, examine the sting and parts attached to it while they are submerged in a cell filled with water. You see a slender, needle-shaped device whose tip is slightly curved, and which has a bulbous swelling at its base. There is a mass of muscle, and then the poison sac, to the free end of which is attached a threadlike duct. It is easy to understand how the bee can jam the sting into your skin, for that instrument is sharp-pointed and equipped with powerful muscles. But you haven't seen anything yet. You have observed only the sting *case;* inside are the really marvelous parts.

You may find it a bit difficult to force out the two lances or darts that lie in the case, like pocket-knife blades in a handle. Separate the case from the fleshy parts and grasp it firmly with tweezers. Then, by working at the bulbous part with a needle, you can extract the two lances. They look like fine hairs under the dissecting microscope or to the unaided eye; but magnify them 100 diameters!

You are surprised that they are not smooth, but are equipped along one sharp edge with a row of barbs that slant *backwards*. Now you understand why the bee cannot remove her sting, once she has forced it into your flesh. You begin to understand more about the other features of the process—how the sheath enters your skin and opens a way for the lances, which then unfold. However, such small weapons as the sting sheath and lances would hardly make you aware of their presence in your flesh were it not for the

poison that is forced from the sac, through the hollow sheath and into the wound.

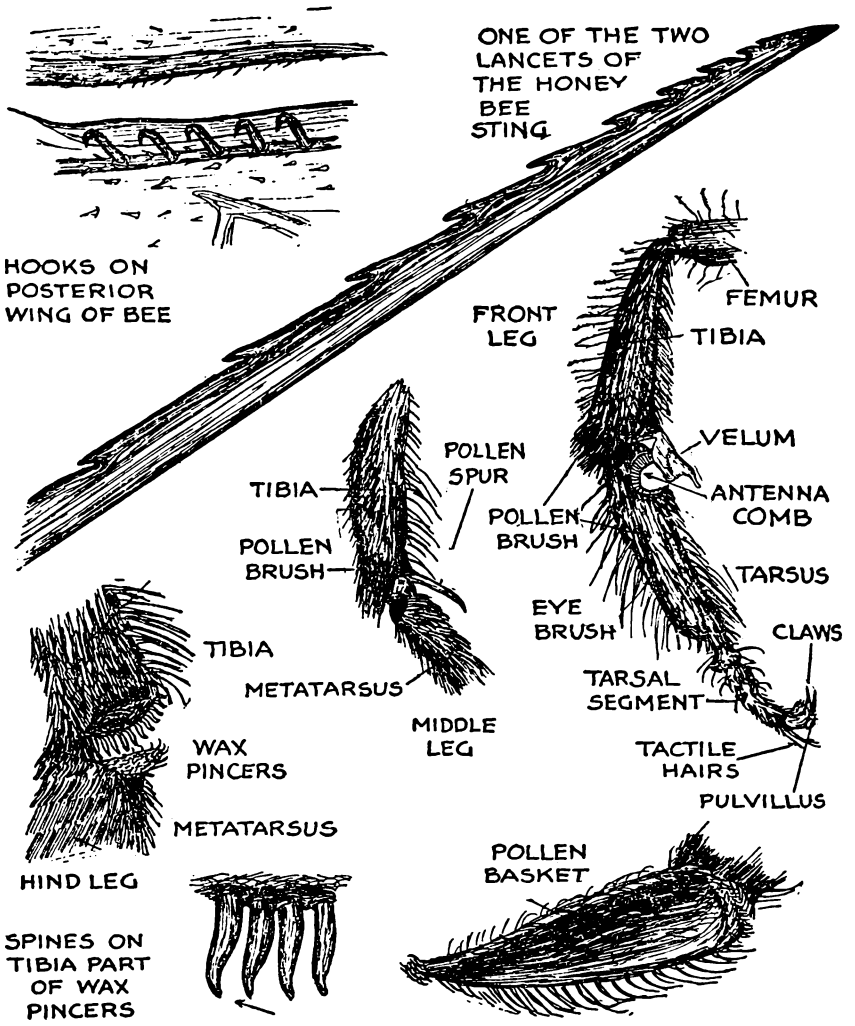
Dry the sheath and sting lances and mount them in balsam, for you will want to show such marvelous instruments to your friends, particularly to those who fall victims to irate honey bees.

Insect wings always are interesting, and those of the honey bee doubly so because of the presence of an ingenious arrangement that increases the insect's flying efficiency. A bee is a four-winged insect. When it is at rest, it folds its forward and rear wings back against its sides; but when it is in flight, it naturally will have greater flying power and control if it can present but a single wing surface to the air. Therefore it has developed an ingenious system of hooks which lock the rear edge of each front wing to the front edge of the corresponding rear one. You can see these hooks, which stand out in rows like the hooks on a butcher's rack, along the front edge of each smaller wing. They fit into a trough in the rear edge of the front wing in such manner that the bee can engage or unhook them instantly. You can see these hooks clearly at 100 diameters; and you will agree that they are worth going to some trouble to examine.

You will find that the bee's wing is composed of a system of hollow ribs or veins over which are stretched thin membranes, like the covering of an umbrella. They are studded on both upper and lower surfaces with spikes or hairs.

Dry a set of wings thoroughly, and mount them in balsam to provide a permanent slide.

The bee's head, with its complicated system of mouth parts and its two large compound eyes on


ONE OF THE TWO LANCETS OF THE HONEY BEE STING
HOOKS ON POSTERIOR WING OF BEE
FRONT LEG
FEMUR
TIBIA
VELUM
ANTENNA COMB
POLLEN BRUSH
TARSUS
EYE BRUSH
CLAWS
TARSAL SEGMENT
TACTILE HAIRS
PULVILLUS
POLLEN SPUR
TIBIA
POLLEN BRUSH
METATARSUS
MIDDLE LEG
TIBIA
WAX PINCERS
METATARSUS
HIND LEG
SPINES ON TIBIA PART OF WAX PINCERS
POLLEN BASKET

either side and three simple ones on top, ought to prove interesting. Dissect out one of the compound eyes and examine it. Note the mosaic of tiny lenses, each capable of forming an image. From the front of the head project the antennae, in which are believed to be located sense organs of smell, touch, and hearing. Covering the surfaces of the antennae are, in the worker bee, about 2,400 smell pits or hollows. The drone is credited with about 38,000, while the queen has to be satisfied with 1,600.

Skip the button-tipped "lingula" or tongue and the other interesting details of the head, for the time being, and hasten to the legs, where a most extensive collection of mechanical devices is found. When you remember that the worker honey bee's principal job in life is to collect pollen and nectar from flowers, you can understand why it has developed such elaborate mechanical equipment in its six legs. Remember that pollen is a fine powdery material, and that the bee must handle this without becoming so covered with it that she cannot see or smell or exercise her other senses. Just as you blow your nose when it gets full of dust, so the honey bee combs her antenna and brushes her eyes when they become coated with pollen grains, using specialized parts of her legs for these operations.

The thorax of a honey bee's body is divided into three segments, and each one bears a pair of legs. First, towards the head end are the prothoracic legs. Then, in the middle are the mesothoracic legs, and finally, at the rear, are the largest of all, the metathoracic legs.

Insect legs are divided into five parts. Beginning at

the body you find, in order, the coxa, trochanter, femur, tibia, and the tarsus that has five joints. The part of the tarsus next to the tibia is called the metatarsus.

Examine a front leg of your worker bee. The first thing that you probably note is the antenna-cleaning device situated between the tibia and metatarsus. In the end of the metatarsus nearer the body, you see a rounded opening lined with an orderly array of spines. At high magnification, they look like a series of round-nosed cartridges in a curved clip. Extending from the adjacent part of the tibia in such manner that it can fold down over this curved notch when the leg joint is bent, is the velum. Whenever the bee finds that her antennae are a bit overburdened with pollen, she simply inserts each one into the toothed notch of the leg nearer it, folds down the velum, and strokes the particles off! Can you think of a more ingenious arrangement?

But that is not all. The compound eyes are studded and surrounded with hairs, which likewise collect dirt. To remove this, the bee uses a row of bristlelike hairs that project from the metatarsus of her front legs, on the side opposite an antenna notch. The coxa, trochanter, femur, and tibia of all legs are covered with long, branched hairs that pick up and hold pollen. At the outer end of the tibia of the first and second legs is a tuft of fine hairs, forming the pollen brushes that are used to remove pollen grains from the collecting hairs.

The five-jointed tarsus of each foot ends in an interesting arrangement consisting of a pair of curved, relatively heavy branched claws with which the insect clings to objects, and between them a pulvillus from

which is secreted a sticky material that enables the bee to cling to smooth surfaces. Hairs cover the tarsus, there being large tactile hairs near the claws.

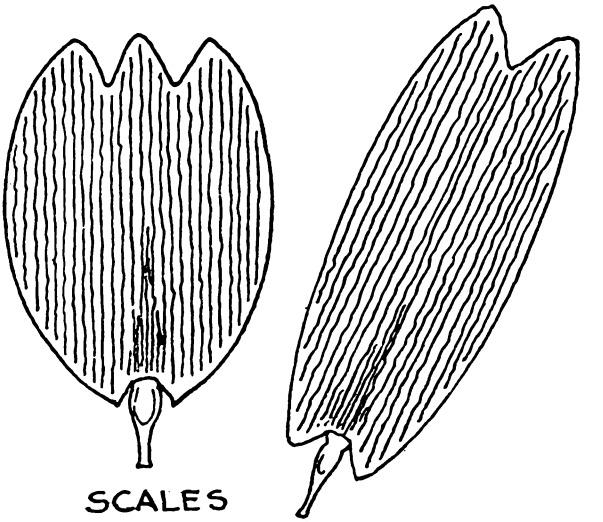
The outstanding feature of the second leg is a long, curved spur extending from the outer end of the tibia. The bee uses this spur mainly to dig closely compacted pollen from the pollen baskets on the third pair of legs.

Now examine the rear legs. You will find them to be much larger than the others, and to be equally hairy. The metatarsus is covered with hairs arranged in orderly rows, looking as if some insect barber had shingled them periodically. Between the metatarsus and tibia is an ingenious tool that will bear examination at high power. This is the wax pincer, used by the bee to pull from her abdomen plates of beeswax secreted by abdominal glands. One pincer jaw consists of a row of orderly and beautifully formed spines set around the edge of the circular end of the tibia. The spines close upon a flat plate on the metatarsus. The surface of this plate is marked by little points, somewhat like the knurled handle of a tool.

Now turn the leg over and closely examine the reverse side of the tibia. You are looking at the bee's pollen basket, the temporary storehouse of her golden treasures. The surface of the tibia is smooth and hollowed, and is fringed by heavy, curved spines which can be folded over the hollow portion. When the basket is laden with pollen, the spines fold over and compact it, and hold it in place.

Now what do you think of the insect world as exemplified by the honey bee? Of course, the bee is not representative of all insects, but it is among the most interesting and important because it is probably the

most highly developed of any. You have only begun to explore its wonders. You should not stop with the details already mentioned, but should learn to dissect a bee and study the wonderful things you find inside —the system of tracheae or air tubes, for instance,



SCALES FROM WING OF A BUTTERFLY

with marvelous reinforcing threads running spirally around them, and the spiracles or air inlets, which are provided with valves that act to prevent the entrance of dust. Some naturalists claim that the breathing systems of insects, as illustrated by the honey bee, are superior to the one-passage type human beings use.

By carefully studying the honey bee with the aid of your microscope, you will learn a vast amount about the class Insecta in general, and will know what to

search for when you come across a strange bug that looks interesting. One thing you should do when examining a new insect is to look for scales. Not all insects have scaly wings or other parts, but some possess beautiful structures of this kind. Moths, for instance, are well known for their scales.

Small insects can be persuaded to give up an abundant supply of scales by placing them in a dry test tube and shaking them violently. You will find there is great variety among the antennae of insects. Do not overlook the beautiful, feathery antennae exhibited by some moths. The proboscis of the mosquito, the moth and nearly every other insect is worth studying. The wing cases of beetles frequently are very beautiful when viewed with the microscope by reflected light. The noise-making wings and the gizzards of crickets should not be overlooked.

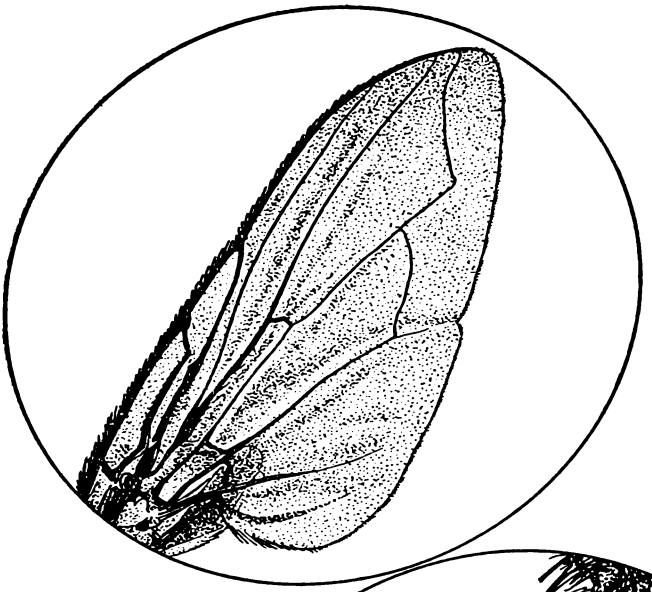
And then there are the spiders which deserve special attention because they have eight legs and are among the most capable engineers of the insect world. Furthermore, as if anticipating that you would want to study it with a microscope, the spider that you see building webs in hedges, on bushes or in the corners of buildings has provided you with specimens that are ready to be mounted on a microscope slide without further preparation. These are the skins that the spider sheds at intervals. The shed skin is as good as the spider itself for studying such details as the jaws, legs, and hairs. You will find the skins somewhere in the web. Perhaps you have seen them many times and thought them to be dead spiders. Handle them carefully, for they are lighter than a feather and very fragile.

You will discover that the spider has six pairs of appendages extending from its body. There are no antennae as in insects. The walking legs apparently take their place to some extent. The first appendages, beginning at the head, are the chelicerae. In many spiders these are composed of a curved fang attached by a hinge to a base or mandible. The fang, when not in use, folds down into the mandible like a blade in a pocket knife. You may be able to detect, at a higher magnification, a tiny spot near the tip of the fang through which poison is ejected from glands inside the spider's body. This poison is powerful enough to kill the flies and other insects that the spider uses for food, and in some cases is potent enough to affect larger animals. Most spiders are harmless to man, there being only a few really dangerous ones, such as the Black Widow.

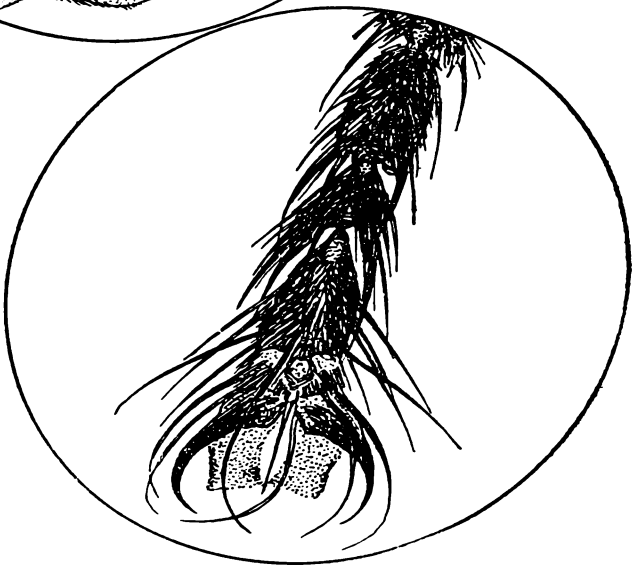
Next after the chelicerae are the pedipalpi whose bases are employed for crushing insects so that their juices can pass through the mouth into the sucking stomach. The pedipalpi of male spiders are used in the reproductive process.

You will find the next four pairs of appendages, the walking legs, interesting, particularly their terminal claws. It is the spider's eight legs that distinguish it from the six-legged insects. Each spider leg consists of seven parts, namely, beginning at the body, the coxa, trochanter, femur, patella, tibia, metatarsus, and tarsus. You will notice that most of these parts correspond to those you observed in the honey bee.

You will observe, in examining a leg from one of the shed skins, that the feet are composed of a pair of claws bearing comb-like teeth on their curved sides,



WING
OF
HOUSE FLY



FOOT
OF
HOUSE FLY

with a smaller claw set between their bases. The legs are covered with hairs, mostly branched. There may also be a pad of hairs on the feet. The claws and hairs enable the spider to cling to its web and to rough objects, while a sticky fluid apparently is secreted from the pad which enables it to travel on smooth walls and ceilings.

At the posterior end of the abdomen, you find the spider's silk factory, or at least the external parts of it, the spinnerets. There are three pairs of these, and each contains scores of tiny openings through which the web-making fluid emerges from the silk glands in the body. Spinnerets are covered with hairs.

"Why," you ask, "are there so many silk tubes?"

The answer is: "Speed!"

When a fly blunders into a web, the spider dashes out to make certain that the fly will not struggle free. It sinks its fangs into the fly's body and injects the poison that kills or paralyzes it. Also, so rapidly that you find difficulty in following the process with your eye, the spider binds the fly tightly in a silken envelope. It is to make such lightninglike silk spinning possible that the spinnerets are equipped with a large number of silk tubes. Were the silk fluid to issue from one or at most a few openings, it would not harden instantly into strands because the air could not get to it, as it can when there are hundreds of fine threads.

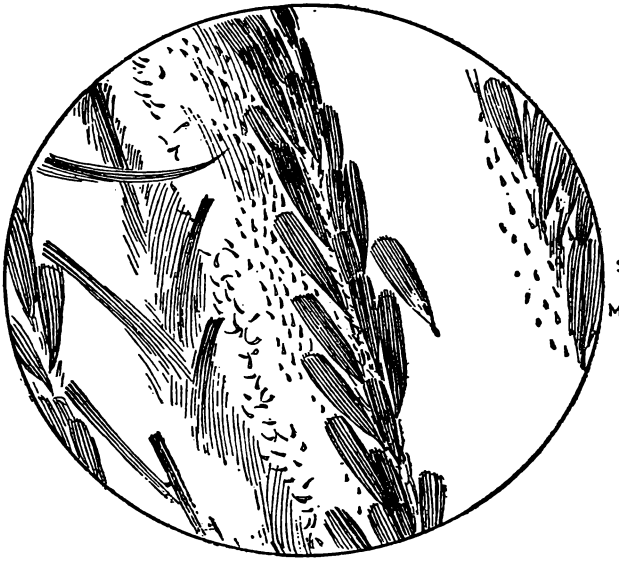
Arranged on top of the head towards the front are the spider's eyes, usually eight in number. Under a low magnification, they glisten like tiny jewels. The arrangement of the eyes varies with different species, and forms one basis for classification.

To appreciate the spider's ability as an engineer,

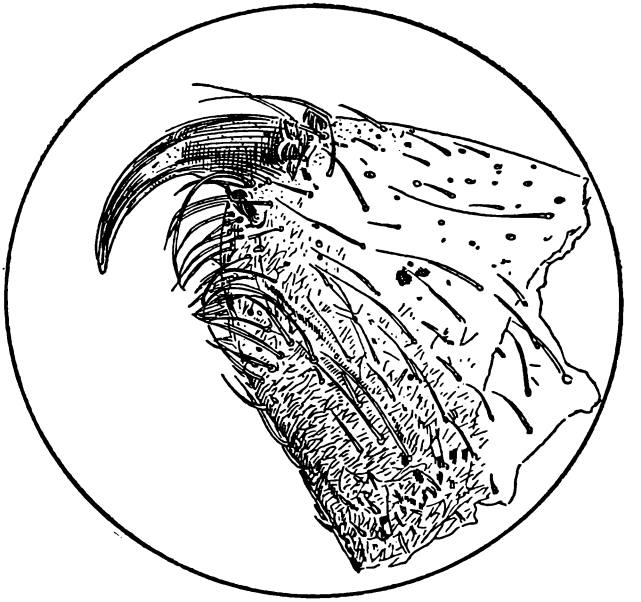
you must examine its web. The web of the orb spinner, which spreads like a silken sail between weeds or the branches of a bush, is among the most beautiful and interesting. At its center, where the spider has made a little platform by placing a great many silk strands close together, you will find the master craftsman, crouching in wait for a luckless insect. Examine the web, and note its form. Radiating from a common center are a great many heavy silken cables, running straight or nearly so. Their outer ends are attached either to twigs or to other cables that extend between solid supports. Connecting these main strands are other strands running in a general spiral direction.

Into the edge of a block of ½ inch soft pine drive two common pins, so that they are about ¾ inch apart and project from the wood for about three-fourths of their lengths. Carefully detach from the orb web several strands of silk in such manner that they will extend from one pin to the other. Obtain both radiating and spiral strands. Place the block on your microscope stage and focus on the web material. You will find that the straight, radiating silk threads are smooth. But when you look at the other threads, the ones that the ingenious spider had arranged in a spiral or circle, you see a different picture. Spaced along the silken filament are little globules that glisten in the light like jewels. Touch them with your finger or a needle, and you will find that they are sticky, like molasses. It is these little beads that catch and hold fast the fly that wanders into the web. The spider, then, was the inventor of fly paper!

And so, by subjecting the spider and the honey bee to the powers of your magic tube, you have learned



WING SCALES OF MOSQUITO



FANG OF SPIDER

that there are many wonders to be found in the part of Microland occupied by the insects and their eight-legged relatives. Likewise, by similar observations on higher animals, you will discover a new assortment of fascinating details that will make it difficult for you to decide which division of the Animal Kingdom is the most marvelous.

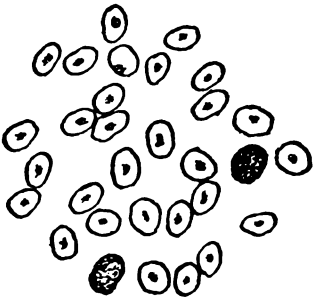
When dealing with the larger animals, the frog and the chicken and the hog and the steer, you will have to proceed differently, and with a little more difficulty. You can tear off a bee's leg and put it on a microscope slide, but you cannot do that with a steer. Instead, you will have to go to the butcher shop and get some beef from which you can cut thin slices to be stained and mounted for observation.

The blood is so important a part of the higher animals that you ought not overlook its wonders. That of the frog is particularly suitable for microscopic examination because the red corpuscles are large. You can see this blood actually being circulated through the capillaries—the tiny veins in which the blood exchanges its oxygen for waste matter from the tissues—of a frog or tadpole without harming the animal in the least.

When employing a tadpole, arrange it on a slide so that you can focus on the thinnest part of its tail. If you use a full-grown frog, you will have to make a wooden platform on which you can bind it with wet cloths while you carefully anchor its foot in such a way that you can look through the thin webbing between its toes. With the microscope focused on a capillary, preferably at a point where it branches, you can watch a fascinating spectacle; you can see the

blood flowing through the tiny tubes, the flat, disk-shaped red corpuscles tumbling over each other in a striking manner.

Frog blood makes an interesting permanent specimen. Place a drop of it on a slide and, with the end of another slide, spread it out in a thin film. Fix either by heating in a fairly warm oven (about 275 degrees), by flooding with ethyl alcohol, draining and burning off with a match, or merely by letting alcohol act on



FROG BLOOD

the film for 2 minutes. Stain for 10 minutes or so with Delafield's haematoxylin. Wash for a few minutes in water, and then stain for not more than a minute in eosin. Wash, dry, and examine or mount in balsam. You will find that the nuclei of the blood cells are purple, and that the surrounding protoplasm is pink.

In fresh blood of a frog or other animal, you can see two principal kinds of corpuscles. The red corpuscles are by far the more numerous. Then, here and there, you will find colorless cells that look like Amoebas, and that, when alive, possess the power of

locomotion. These are the white corpuscles that have the important duty of capturing and devouring disease organisms that get into the body.

Bone is an interesting material when seen through the microscope. You can make it as soft as ordinary tissue, and so make possible the cutting of thin sections, by removing the calcium. First let a small piece of the bone remain in 10 per cent formalin for a day, and then transfer it to dilute nitric acid. In about a week the piece should be completely decalcified. Wash it in a solution of baking or washing soda to remove the acid, then in clean water. Cut it into thin sections by any of the methods already mentioned.

Because of the limitations of space, only a few of the wonders you will encounter in the world of insects and the higher animals have been mentioned. You will have no difficulty, with your microscope to help you, in unearthing thousands of other marvels totally unknown to the person who never looked through a magic tube.

CHAPTER V

CRYSTALLINE WONDERS

THAT the microscope is a delightful instrument is fully demonstrated when you turn it on the rare gems of Microland, the crystals. You will discover, perhaps with amazement, that some of the most common substances possess a crystalline beauty that you never suspected. A pinch of common salt will become, under your microscope, a hundred cubical jewels that rival the diamond in their clear, sparkling beauty. You will find that you have been devouring, in your cup of morning coffee, millions of sparkling gems that made up the lumps of sugar with which you sweetened it.

Get out your microscope, a dozen clean slides, several glass tumblers, and actually study some of the microscopic gems at first hand.

In a glass one-eighth full of hot water dissolve as much salt as possible. Place a drop or two of the solution on a slide, and let it remain for a few minutes. Then drop a cover glass over it and look at it. The little cubes you see are salt crystals. Some are perfect, others seem to have designs on some of their surfaces—designs worked out with geometric exactness by arrangement of squares. Here and there you may see crystals that are not cubes. They are the crystals of impurities contained in the salt. If you em-

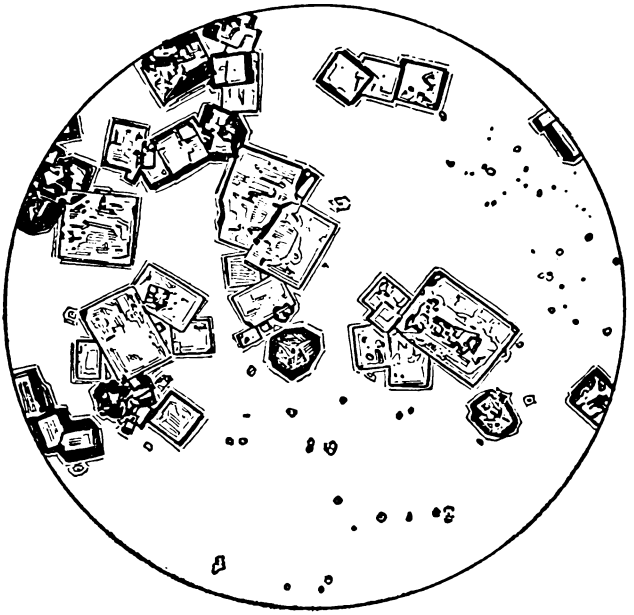
ployed iodine salt, you probably will see crystals of some iodides.

Already your microscope has revealed one of the most important facts known to chemists: When a solution containing more than one substance crystallizes, the resulting solid consists of a mixture of crystals, each of which is composed of but a single chemical substance. This action makes it possible to purify chemicals by crystallization. The mixture of different crystals can be separated by dissolving one kind in a solvent that does not dissolve the others.

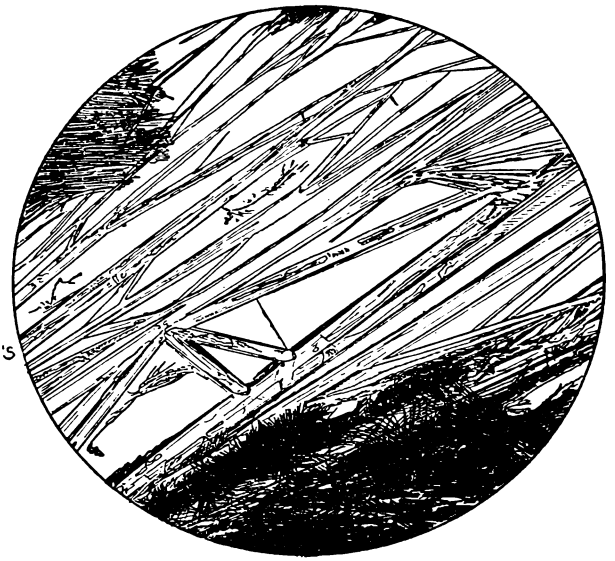
Study the salt crystals, and make a mental note of their form and appearance. Then whenever you encounter them in butter or any other substance that you might put under the microscope, you will recognize them instantly. Crystals are the keys that enable the expert microanalyst to identify minute quantities of drugs and poisons and other substances, when the chemist or other expert fails.

Again to the kitchen. This time, make a saturated solution of baking soda by dissolving as much of it as you can in hot water. Evaporate a drop on a slide, watching the process through a low magnification, say 50 or 100 diameters. You will see the needlelike crystals appear first as minute specks, and then grow rapidly into their characteristic forms. They mat together into a maze, resembling somewhat masses of vegetation; a chemical cactus patch!

The four-sided prisms into which sugar crystallizes are familiar to everyone who has eaten rock candy. You can produce such crystals by making a strong solution of sugar and letting it crystallize out on a string or the container.



SODIUM CHLORIDE CRYSTALS TABLE SALT



PYROGALLIC ACID CRYSTALS (PHOTOGRAPHER'S PYRO)

The photographer's darkroom is overflowing with the most fantastic jewels, bits of beauty that far surpass any crude piece of art that he might produce with negative and paper. If you can obtain some of his chemicals, you have material for a fascinating evening. Ask him for some pyrogallic acid that he calls "pyro," some hydroquinone, one of his most important developing agents; some potassium bichromate, and whatever other water-soluble materials you can beg.

Dissolve small quantities of the chemicals in water, generally hot, to form saturated solutions. Then place a drop or two of each on a clean slide, and let the water evaporate. That is the usual method of preparing crystal specimens from solutions.

It is difficult to say whether the pyro, the hydroquinone, or the potassium bichromate produces the prettiest pattern. Place the slide containing the pyro solution on the microscope stage before the water has evaporated, and focus on it with a low power. Introduce a few fragments of some insoluble material such as the scrapings from a pencil lead, and watch what happens. In a short time, you will see each separate particle become the center of an amazing pattern of long, slender crystalline needles. They will branch out in all directions, like a fantastic feather. At another place the needles may, for no apparent reason, trace a complicated curved or spiral design. Along the edges of the drop will form the larger, more complicated masses of crystals. On the whole, it is a picture of breath-taking beauty that photographer's pyro can produce. With dark-field illumination, it is even more striking.

You will find that the potassium bichromate has

crystallized into a forest of plants built up of orange-red crystals. The arrangement of these chemical shrubs varies, but frequently the effect is strikingly like that of a thin-foliaged hedge growing out of a grass-covered soil. At higher magnifications you can see that the crystals are not symmetrical in form.

The hydroquinone, an organic compound, crystallizes in a pattern that resembles, in some ways, frost tracings on a window pane in winter. Row after row of slender lines, made up of tiny crystals, runs across the microscope field. There will be an orderly array of parallel lines extending in one direction for a certain distance; then suddenly the pattern will change, the lines running in another direction. At some places the lines will unite to form a cross-hatching. On the whole, it is a striking spectacle.

Potassium permanganate, whose deep purple crystals you can buy and dissolve for making poison-ivy medicine, produces, not an intricate crystal pattern when a drop of the solution evaporates, but a scattered collection of slender, often sharp-pointed needles of rhombic form. Larger crystals generally form at the edge of the drop.

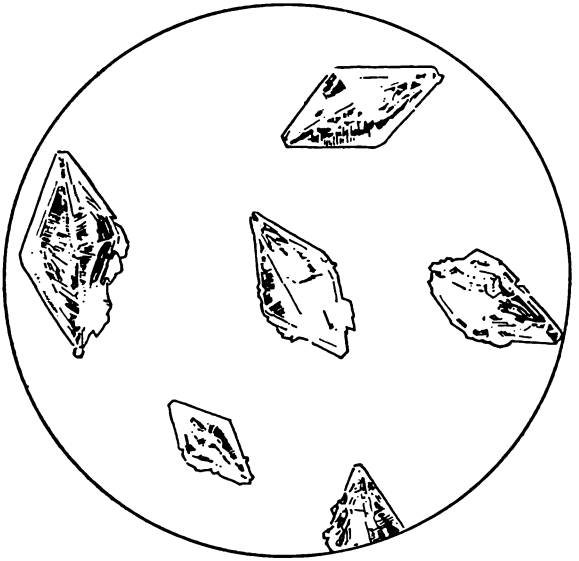
You could go on for the remainder of your life evaporating solutions and examining their crystals or crystalline patterns, and you would not exhaust the store of material. You would find that there are crystals in places other than the residues of evaporated solutions. Most precious stones are crystalline in form. Quartz, whose crystals help keep radio broadcasting stations on their wave lengths, is one of the interesting and important minerals not classified as precious. Some of the crystals, you would discover, are

too large to be considered as microscopic specimens.

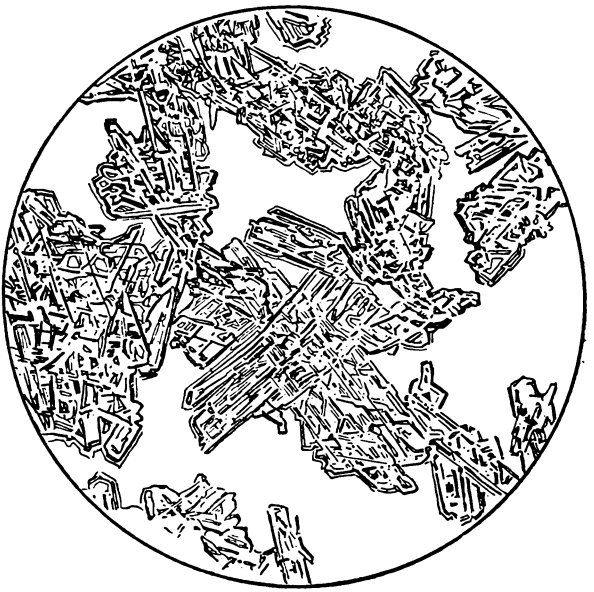
Sometimes a substance exists in more than one crystalline or solid form. Sulphur is a good example because you can produce its two crystalline forms yourself. Melt some sulphur in a porcelain dish or a tin can, being careful not to let it catch on fire, because the fumes are disagreeable and, in sufficient quantities, poisonous. Let the sulphur cool until all but the center of the mass has solidified. Pour out the remaining liquid, and you will find a maze of long, slender crystals of monoclinic sulphur. The crystals are transparent and pale yellow. After a time, at ordinary temperatures, the crystals lose their transparency and become masses of rhombic sulphur.

The best way to prepare rhombic crystals is to dissolve some sulphur in carbon disulphide and then let the solvent evaporate (Caution: carbon disulphide is very flammable and explosive, so keep it away from all forms of fire). A good way to evaporate the solution is to pour out on a level sheet of clean glass enough of it to form a little pool. The crystals will be distributed evenly over the glass, provided the arrangement is not disturbed during evaporation. There will be crystals of various size, little yellow gems that are distinctly visible to the eye but, when transferred to a slide and observed at 25 or 50 diameters, are much more striking and interesting. Most of the forms of sulphur, such as natural and roll sulphur and flowers of sulphur, are of the rhombic system.

The thousands of crystals known can be grouped, according to their forms, into a relatively few classes. Some of the more common ones are illustrated. The alum crystal is a good example of the octahedron form.

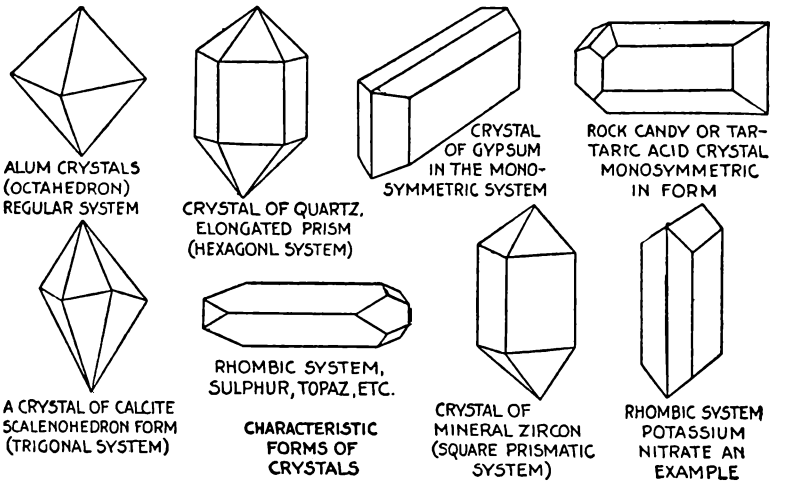


RHOMBIC SULPHUR CRYSTALS



ASPIRIN CRYSTALS

The mineral zircon exhibits the square prismatic form. The rhombic system includes crystals of potassium nitrate (niter), sulphur, topaz, etc. Among the monosymmetric crystals are those of gypsum, tartaric acid, and cane sugar. Quartz, already mentioned, is found in elongated prisms of the hexagonal system. Calcite exhibits a scalenohedron form (trigonal system).



Among the asymmetric crystals are those of potassium bichromate, which, you remember, produces a microscopic forest.

Strictly speaking, all true solids exhibit crystalline forms. Materials such as glass, which generally are considered as solids, really are amorphous. Glass is not a solid but a liquid in a highly viscous state.

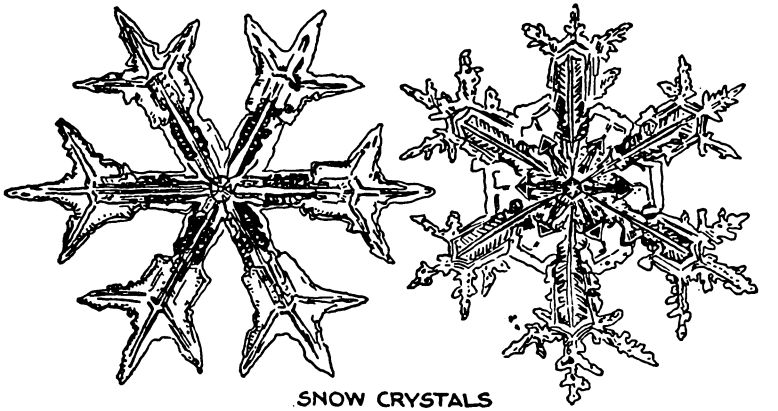
Chemists used to attach much importance to the classification of crystals on the basis of symmetry. The

science of crystallography has been built up about such a classification. Today, however, crystallography is concerned mostly with the recognition of substances, while the chemist has learned that the inside of a crystal is, to him, more important than the outside.

It was by reflecting X-rays from suitable planes of crystals that scientists learned how the atoms inside are arranged. Every substance produces a pattern peculiar to itself. From the results of X-ray studies, it has been possible to construct models showing the position of every atom of matter inside various materials. Common salt is chemically known as sodium chloride. The X-rays showed that groups consisting of four atoms of chlorine and four of sodium are arranged so that there is one atom at each corner of a cube, and that the materials are alternated around the edges. The length of one edge of such a cube is about 1/100,000,000 inch, which is hardly large enough for the microscope to see! The salt crystals that are visible as cubical gems are made up of countless numbers of the tiny atomic cubes, each arranged so that its corners containing sodium atoms are adjacent to other cube corners containing chlorine atoms.

So, when you gaze through your microscope at a remarkable display of crystals and wonder what divine force has acted with mathematical exactness to produce such forms, you can find the answer in the chemist's and physicist's X-ray patterns. It is, in short, the arrangement of atoms within a substance that determines its crystalline form. Snow flakes always are six-pointed because of the definite arrangement of the atoms of hydrogen and oxygen forming the water.

Speaking of snowflakes, you will find them among the most fascinating of crystals. Transport your microscope and a few slides outside or to the garage when the weather is below freezing and the snow is falling, and let them remain there until they have become as cold as the outside air. Hold a chilled slide where snowflakes can fall upon it. When you have several



SNOW CRYSTALS

specimens, place the slide on the stage and focus, using a low magnification. You probably will not forget soon the first perfect snowflake you see under the microscope. Few things in nature are more delicately beautiful.

The snowflake at which you are looking has six points or sides or projecting arms. You can predict that before you see it; but you cannot predict what its exact shape will be. No one ever saw a flake like it before, and no one ever will. Of the billions of snowflakes that have fallen, no two were alike, as far as

science has reason to believe; yet all of them were built on the six-point plan!

After you have tired of snowflakes, you can proceed to another form of crystalline ice, the frost designs on a window pane. It is a bit difficult to put a window pane under your microscope lens; but you can hold your microscope against the glass and focus on the frost; or breathe on a cold slide and then study the crystalline pattern into which the moisture from your breath freezes. You will find that it resembles, in some respects, the beautiful patterns traced by chemical substances when they crystallize from solution.

If you have a microscope or hand lens that can be used like a reading glass, you can study snowflakes without elaborate preparation. Simply put on an overcoat, go outside when it is snowing, and observe, through the lens, the flakes that fall on your coat sleeves. Usually you will have to select the perfect flakes from among the clumps of ice crystals that fall with them. When there is no wind, and the snow is cold and dry, you will find the best flakes.

Metals, being solids, exist in crystalline forms. The microscope is an indispensable instrument in the metallurgist's laboratory because it enables him to see the crystals that make up the steel or copper or brass with which he is working. You, too, can investigate some of the wonders of metals, with your microscope.

Here, for example, is a piece of steel. To your unaided eye it presents a smooth surface. Under the microscope the surface is marked with many little grooves and ridges where the metal was scratched as it was thrown about in your junk box; but you see no

crystals. Nevertheless, they are there, but they need special treatment to make them visible.

First you must polish the metal. Procure some powdered emery, preferably of two or three grades of fineness, and rub some of each grade into laps formed by tacking several thicknesses of cloth to a board. Make another lap and rub jeweler's rouge into it. File a flat place on the metal and polish first with the coarse emery moistened with water, and then progressively through the finer grades, finishing with the rouge. The final polish should be mirror-like.

The next step is etching. An easy and quick way is to dip a glass rod into concentrated nitric acid and transfer a drop to the dry, greaseless, polished surface of the metal; then quickly plunge the metal under a stream of water from a faucet, or pour water over it with a beaker. During the instant that the acid is being diluted with the water, etching of the metal takes place; but the water washes the acid away immediately, preventing too deep etching. Dry the piece of metal by gentle warming, without touching the polished surface with your fingers. Mount it either on the microscope stage or directly below the hole in the stage, and examine by reflected light, preferably a concentrated beam from an arc or projection lamp. If you find that the etching has not been deep enough, repeat the nitric-acid treatment.

The picture that will unfold before you will depend entirely upon the nature of the metal and the degree of etching. You will see a patchwork that probably is made up of carbon, iron, and a number of other materials, most of which are impurities. Perhaps you can see a formation that, because it is composed of fine

lines or layers like mother of pearl, is called pearlite. The crystalline structure of the metal, although generally revealed by the process just outlined, may be indistinct because of some processing through which the specimen has gone. It is a good idea to anneal the specimen by heating to redness and then cooling, before polishing and etching. Cast iron is easy to etch so that it shows its structure. It differs from steel in having more carbon, some or all of which may be in an uncombined state.

You will find it worth while, if you are interested in metals, to consult books on metallurgy, and learn how to prepare specimens of copper, various steels, zinc, aluminum, and the numerous other metals and alloys for microscopical examination. There are a lot of little tricks that cannot be discussed here, such as ways to etch for different colors and different degrees of relief.

The preservation of crystals of potassium permanganate, sulphur, hydroquinone, and numerous other materials on permanent slides is not difficult. You can preserve the lacy patterns traced by some crystals simply by dropping a little Canada balsam on the specimen and adding a cover glass. Perhaps certain crystals will not keep well when thus mounted, but that is something you can learn by trial. Large crystals, such as those of rhombic sulphur, can be mounted in deep cells by covering the bottom of the cell with a thin layer of balsam, arranging the crystals with tweezers, letting the balsam harden, and then cementing a cover glass over the cell. Mineral crystals can be mounted the same way.

You will be so struck by the beauty of some of the crystalline forms that you will want to draw or photo-

graph them. In fact, a file of photomicrographs of steels or other materials may be of considerable value to the person who uses them extensively. But whether it is the sheer beauty of design or some other quality that you wish to preserve, you will not find it difficult.

CHAPTER VI

RANDOM WONDERS

"AT what shall I look?" is a question that seldom bothers the owner of a microscope. There are so many interesting subjects to be found in and about the average home, or wherever else the microscopist happens to take his magic instrument, that the need is likely to be more for time than for material. However, with the thought that a random list of microscopic wonders might be useful at times, the following suggestions are being offered:

AMBER: Perhaps someone in your family has a string of amber beads, or a brooch made from this substance. With a low power of your microscope, examine the amber, and the chances are that you will discover that it contains insects and perhaps bits of plants, captured and imbedded ages ago before the resin from a prehistoric tree fossilized to form the amber. Rough pieces of amber can be ground flat with fine emery paper and polished on a smooth stone, to make the imprisoned objects easier to see.

ANTS: Among the most fascinating little busybodies that you can capture in your garden or almost anywhere else are the ants. They are surpassed only by their cousins the honey bees in the degree of their insect intelligence. Among their many community activities are the keeping of cows and the raising of

gardens. To examine an ant with your microscope, first kill it in alcohol or strong carbolic acid. Inspect its feet, mouth parts, antennae, and other features. Perhaps you will want to become a skillful surgeon and see something of its interior wonders. A needle, ground to the form of a very slender and sharp knife blade, will be useful in dissecting it while it is submerged under water. For a permanent slide dry the ant and mount it in balsam, in a deep cell.

BARNACLES: Do you visit or live near the sea? If so, take your microscope on a barnacle-hunting expedition some day. These marine animals grow on ships' hulls, underwater piling, rocks, and other submerged objects. The barnacle lives in a cleverly constructed tepee equipped with an ingenious valve at the top. Opening this valve, he reaches forth a 24-fingered hand, covered with hair, and grabs choice bits of food from the water. This hand is worth studying with your microscope. If you are lucky enough to capture a baby barnacle, you will find that it resembles a tiny water flea.

BEETLES: The beetle will provide you with a surprise or two. You never know whether to expect a beetle antenna that looks like a string of oval beads or a branch with overlapping leaves, until you become familiar with the owner through your microscope. You will find the hard wing cases of these insects interesting, and some of them extremely beautiful because of the presence of tiny light-reflecting scales. Some beetles have mouths mounted at the ends of long, jointed tubes, with a pair of antennae midway between the mouth and body.

CICADAS: The Seventeen-year Locust and Dog-Day Harvest Fly are members of the Cicadidae family that

springs into prominence every 17 years, when the locusts appear. Males are like modern theaters, wired for sound. You can see, on the belly, large, irregular plates or drum covers. Beneath these is a system of sound-producing organs that is amazing in its complexity and efficiency.

COAL: See Fossils.

CRICKETS: "Chirrrrrup," comes the sound of the cricket's voice from beneath the basement stairs. Capture him, and examine his wings. Note that they are equipped with drum-like membranes, and have toothed saws used in producing sound. Pull the head from a cricket, and the chances are that you will extract the dark-colored gizzard. Slit it open, wash out the inside with a dropper, mount it in water and examine it for grinding teeth.

CRYSTALS, METAL: There is beauty in the brass hinge on your microscope case, in the knife blade you carry in your pocket, and in the cast-iron doors of the furnace—hidden crystalline beauty that must be brought to light by special treatment. To make visible the wonders of metal crystals, you first must polish a flat piece with fine wet emery or an emery stone, and finally with jeweler's rouge distributed over a wet cloth tacked to a board. When the surface glistens like glass, it is ready to etch. For iron and steel you can use dilute nitric acid or iodine. For brass, use a mixture of about equal parts of hydrogen peroxide and ammonia water, performing the operation in the open air. A few trials will show the proper degree of etching. When viewed as an opaque object at moderate magnifications, the crystalline structure of the metal should be plainly visible.

CRYSTALS, PLANT: Jewels in plants! They are mentioned elsewhere in this book, but a few additional remarks on their source and form may be helpful. You can find plant crystals generally in individual cells in the leaves or other parts. Needlelike crystals, often in bundles, are found in such plants as the primrose, spiderwort, lemma, forget-me-not, and Virginia creeper. Elongated prismatic crystals occur in the iris, aster, thistle, and gladiolus. Crystals that appear generally ball-shaped can be seen in oleander, geranium, portulaca, mallow, and hibiscus. Crystals not coming under any of these classifications, and which include short prisms, cubes, etc., occur in clover, maple, onion, and many other plants.

DANDELION: What were the brightest spots on the landscape today, when you were driving through the country? "Dandelion blossoms," you answer. You brought some home? Good. You are going to be pleasantly surprised. Split one of the blossoms in two and remove one of the golden rays. Under your microscope, you find that it is not as simple as you thought. From the bulbous base there extend numerous slender threads bearing clumps of pollen. The threads, the pollen, and the remainder of the ray look like a tiny flower. It *is* a flower, for the dandelion blossom really is a whole bouquet of little flowers held in a living vase! The goldenrod, sun-flower, aster, daisy, and chryanthemum also are composite flowers.

EARTHWORMS: When you went fishing and put a fish-worm on your hook, did you know that you were handling a good 3 inches of microscopic wonders? The earthworm, once you get to know it better, is one of the most interesting creatures you can study with the

aid of your microscope. It is not difficult to dissect a good-sized worm, using as an operating table a shallow pan partly filled with paraffin into which you can stick pins to keep the worm from sliding all over the place. Just to mention one of the many wonders, there are the setae. You would call them feet. There are four pairs of them to each segment of the body, except the end ones. The setae look like ∫-shaped glass rods extending from the lower part of the body. It is by means of these feet that the earthworm hangs on when you try to pull it from a hole in the earth.

EMBRYO PLANTS: Every bag of beans is a microscopic garden, for in every seed there is, hidden between the two halves of the cotyledons, an embryo plant with stem and leaves. Put a few beans on a pad of wet cloth for a few days, and you will be able to observe the marvelous manner in which these embryo plants spring to life under the influence of the moisture. Most other seeds contain miniature plants waiting for a chance to grow up.

EPIDERMIS OF LEAVES: Tear an iris, lily, or hyacinth leaf in two, in such a manner that a fragment of very thin, colorless membrane will cling to one of the pieces. This is the epidermis or skin of the leaf, a layer of cells that contain little or no green coloring matter, but often possess other and more amazing features. The lower epidermal layers of many leaves contain prominent pores through which the leaf breathes. Wandering Jew is a good plant to study in this connection. The epidermis of leaves also gives rise to numerous types of plant hairs.

EUGLENA: This lively little one-celled animal, with a whip extending from its mouth, can be found in

abundant quantities in the summer, but frequently is scarce in the winter. You can insure a winter supply by putting into a shallow container some water containing Euglenas, together with some sticks and dead leaves. Let the water evaporate. As the sediment dries, the Euglenas will go to sleep, like tiny bears, and remain that way indefinitely, or until they are placed in water once more. This Euglena seed is easily distributed among your friends who have microscopes.

FEATHERS: Close relatives of animal hairs, feathers appear in a wide variety of forms. Rare bird feathers can be obtained by visiting the bird cages of zoos. Mount and observe them dry. Put a piece of feather from a chicken or goose wing under your microscope. Observe how the beards that make up the vane are fastened together by tiny barbs. Now look at a body feather, and see the arrangement of barbs along the central stem. At higher powers, you find that these barbs themselves carry tiny hairlike filaments which in turn are barbed! No wonder a bird's feathery coat holds together so well!

FERNS: On the underside of fern leaves, you will find little rustlike spots. Cut a piece of leaf off and place it on a slide. Focus on one of the spots. You see a collection of little balls, each anchored firmly to the leaf. Inside the balls are smaller ones. These are spores in their cases, and the group of cases makes the rust spot visible to the eye. A string of beadlike formations encircles the spore cases. These draw together as the spores ripen, until the cases burst and scatter the contents to the winds.

FINGERPRINTS: Why do burglars wear gloves? You can answer this question very easily. Press your thumb

on an ink pad and then on a clean slide or piece of paper. You see a pattern composed of curving lines with spaces between them. That pattern is one of your personal trademarks, for there is no other like it in the world. Look at the fingerprint with your microscope. You see details that were hidden before, and observe more clearly the pattern of the pores in your skin. Fingerprint experts make photomicrographs of such thumb marks and label the various lines and clear spaces, like rivers and valleys on a map. There is a definite system followed in such marking. By comparing the fingerprint maps of suspects with similar prints found at the scene of a crime, police can identify criminals.

FLY: Meet Mrs. Musca Domestica, a "lady" with an extremely bad reputation. You know her better as a House Fly, noted carrier of disease. You can take her life with pleasure, in preparing her for your microscope's searching gaze. Drop her into a bottle of alcohol, or imprison her in a jar and thrust into it a match that has just been struck. The sulphurous fumes will do their work quickly. You will find almost every part of the fly interesting, from the tongue to the feet and their peculiar clinging pads. The fly's eye is a typical example of the compound type found in insects.

FOSSILS: There is a thrill in prying into the secrets of a plant or animal specimen millions of years old. If you have any fossilized wood or other ancient material around the house, inspect it with your microscope. Generally you can find interesting details without special preparation of the specimen. Perhaps you can find a chalky deposit that is made up of millions of tiny limestone shells of Foraminifera, tiny marine

Protozoa. Along the seashore, you can gather sand that contains many intricate and delicately beautiful forms —shapes that an able sculptor could not duplicate. In sand and pond bottoms, you will find Diatom skeletons. But you don't have to wander beyond your own basement for a plentiful supply of fossils. The coal pile is composed of ancient plants that became carbonized through the ages. Split pieces of coal until you find traces of a twig or leaf, and then examine it with your microscope, with light falling on it from above.

FROG EGGS: In any summer pond you ought to be able to find masses of frog eggs. Take a few home and place them in water. With your microscope, you can watch the fascinating development of each egg into a tadpole that swims around inside the shell with the aid of cilia or hairs before hatching, and then loses the hairs a short time after emerging. You can observe the circulation of blood in the tadpole's tail or the webbed foot of a grown frog. The shed skin of a frog is used frequently in schools to illustrate the "pavement epithelium" arrangement of cells.

GRINDING-WHEEL DUST: In such an unattractive place as a pile of grinding-wheel dust, you will find unexpected microscopic wonders. Look at a pinch of the dust at moderate magnifications. You see three things. First, there are bits of crystalline material broken from the wheel. Second, there are twisted, jagged fragments ripped from the metal by the grinding wheel teeth. Third, there are—and here is the most interesting part of all—little balls or pellets of steel. These are the cooled sparks you saw flying from the wheel when steel was held against it. Metallurgists have learned that each kind of steel alloy produces a

definite kind of pellet, and that microscopic examination of pellets makes it possible to identify alloys when other methods fail.

HAIRS: Hair from your own head will provide entertainment for many minutes. Clip off a bit ½-inch long and place it on a slide. At 100 or 200 diameters, you discover that it is covered with scales, marked by fine, wavy lines running over the surface. Split the hair with a razor, or make a long, diagonal cut in it, and you can glimpse something of its internal structure. When treated with hot sulphuric acid, human hairs break down into long, slender cells, smaller than those found in other parts of the body. You will have a lot of fun examining hair from dogs, cats, bats, insects, and every other available source. Positive identification of furs and wool cloth can be made with the microscope. If you are interested in plant hairs, you can find no better source than the leaf of the geranium, tomato, nettle, or mullein plant.

INSECTS: Every insect is a gold mine of microscopic material, as has been pointed out. Some microscope workers recommend liquid petrolatum in preference to other materials for immersing small insects for examination. Petrolatum has superior optical properties. Completely dried insects can be mounted permanently in it, by ringing the cell with cement. Another way of preparing beautiful insect slides is to kill the specimen in strong carbolic acid and then mount it in balsam. The insect is rendered more nearly transparent by this method.

INSECT EGGS: Inspect the leaves of the plants in a garden. You will find some on which are clusters of little, jewel-like eggs. Under the microscope these eggs

surprise you with their shapes and markings. Observe them as opaque objects. Sometimes you can find the shells after the larvae have emerged. These you can inspect by transmitted light.

JEWELS: If you can borrow a pin or ring containing a diamond or other precious stone, you will gain better appreciation of the gem-cutter's art. Each tiny facet, at 100 diameters, reveals exactly how accurately it has been cut. You probably will be surprised at the amount of dirt that collects about the gems and tends to dim their beauty.

LEAVES: Plant leaves, whose epidermis has been mentioned under that heading, are available at all times. Few objects are more interesting to inspect. You can put a leaf on a slide and spend hours studying the tiny hairs that grow from its edges or the breathing pores on its surface. Then, tiring of this, you can slice the leaf into thin sections and spend more hours prowling among the cells that make up its structure. A piece of cork makes a good butchering block for slicing leaves with a razor. Try on leaf sections all the microscopic stains you have, and experience some of the most beautiful sights imaginable!

LEECH: If you had lived a hundred years or so ago, the doctor probably would have applied a leech to your skin when you became ill, to bleed you. The leech is a blood-sucking animal that is of interest to the microscope owner because it has, in its tiny throat, three interesting objects. These are teethlike instruments with which it cuts through the skin of its victim. Dissect one of them out and place it under your lens. An orderly row of glasslike cutters, extending along one edge, greets your eyes. These the leech uses to saw

through the skin after it has drawn it taut by a sucking action.

LICHENS: Halfway between the fungi plants and the algae plants are the lichens, familiar as the gray, brown, silver, black, green, yellow, or white scaly growths on rotting trees and old shingles. The microscope reveals that these unattractive plants really are things of beauty. The gray scales are shown to be covered with small spots, the spore cells. These produce spores that are blown about until they land in a suitable place and start new lichens. Because the lichen cannot grow its own food and water and must live off other plants, it sometimes forms a partnership with its relative, the algae. Look at a section of green lichen and you can see the green algae strands enmeshed with the threadlike cells of the lichen. The partnership is mutually beneficial: The algae uses water that the lichen captures and holds, and in return manufactures food for the lichen, from sunlight and air!

LIVERWORTS: The Liverwort is the frog of the Plant Kingdom. Able to live on land, it cannot get along without a lot of water. The liverwort, under the microscope, is one of the most entertaining of wonders. It resembles a mat of leaves that grow out of each other without bothering to produce stems. The underside of the mat is whitish in color, with many threadlike rootlets that collect water and food. The upper surface is green, and the leaves are marked with peculiar warts or projections. These form the equipment that produces new liverworts. Some of the projectons resemble tiny, fringed umbrellas, while others look like star-shaped toadstools. Only one form appears on a single leaf. The toadstool produces swimming cells that enter the

umbrella structure and unite with ball-shaped cells there, to form spores that are blown about until they start new colonies. You can find these interesting plants in damp places, among the rocks of river banks, and in marshes.

MOSQUITO: In the same class as the house fly is the mosquito that has gained a world-wide unpopularity by inflicting discomfort and disease upon a suffering world. With your magic lenses you can explore the wonders of the mosquito's proboscis, and discover the amazing assortment of tools contained there. The mosquito larva or wriggler, which you can find in a rain barrel or stagnant puddle, is a ferocious-looking but entertaining individual. Imprison it in a deep cell and watch its frantic efforts to break through the cover glass. It is attempting to stick out its breathing tube for a breath of air. Soon it will suffocate. If imprisoned in an open-top cell, the larva will make regular excursions to the surface for air. Put a drop of oil on the water, and you block his efforts, just as health experts have waged warfare against the larvae of yellow fever mosquitoes, and have thus controlled that disease in the tropics.

MOSSES: Everyone knows a moss-covered rock when he sees one, but few persons not equipped with microscopes know the real wonders that are hidden in the carpet of tiny plants. The moss plants, first of the plant world to venture the production of real leaves, stems, seeds and roots, are so fragile that they have to stand together in great masses for mutual protection. Wash the dirt from a clump of moss and separate out one of the tiny plants. Put it under your lowest power first. You gaze at a collection of wonders. When a

moss spore finds a moist spot, it first grows into an algaelike plant that gives rise to the real moss plants. These plants have stems, leaves and, most marvelous of all, little hood-shaped arrangements on the tips of the stems. These are spore cases, with an interesting life history. First the moss plant grew a seed at the tip of the stem. This seed, without budging from its position, sprouted a root that went down into the mother plant for anchorage, and a bare stem that went upward. At the top of the stem there developed the fool's-cap spore case you see. You are looking, really, at two plants in one. The spore case is covered with a hood. Remove it, and you discover an urnlike arrangement that is fringed with a row of beautiful hairs or teeth, curved inward towards a cone. These hairs assist in sending on their way the spores that are developed in the central spore case.

OIL GLANDS: Did you ever sqeeze an orange peel so as to squirt a spray of oil into a match flame? With your microscope you can see the glands that produce the odorous oil. Slice the peel into thin sections with a razor.

PAINT: When paint, lacquer, or varnish becomes old, it frequently checks or flakes. With your microscope you can see exactly the condition of such protective coats, just as scientists in paint-factory laboratories use the microscope to watch the progress of aging and weathering in test specimens.

PHOTOGRAPHIC FILM: Every snapshot you make is composed of tiny clusters of metallic silver. Your microscope will reveal these in a piece of film that has not been exposed or developed too much. If you own a miniature camera, you can use the microscope to

check the effectiveness of the various fine-grain developers that you undoubtedly will be trying.

PINE NEEDLES: For an unusual sight, slice a pine needle into thin sections, stain each section a different color, and inspect at 100 diameters.

PINE WOOD OR STEMS: Because of its common use, you should not fail to become better acquainted with pine lumber and, if available, a stem from the pine tree. Cut thin sections across the grain, parallel with the grain and directly through the heart, and parallel with the grain but to one side of the heart. Almost any of the common stains will reveal interesting details. In pine wood, you will find the resin ducts the most prominent feature. For permanent preservation, dry the slices and mount in balsam.

POLLEN: Among the outstanding wonders of the Plant Kingdom are the pollen grains. You can obtain them easily by tapping a flower against a clean slide, or using a small brush to gather the pollen. Mount them in water or observe dry. In the process of forming a seed, the pollen grain, which is a male cell, grows and sends out fine tubes that unite with female cells in the flower on which the grain alighted or was deposited by an insect. You can watch this growing or germination by placing some pollen grains in a dilute syrup made by dissolving cane sugar in water, and placing the syrup under your microscope. Use a slide that has a deep cell built on it; or a hanging-drop arrangement. Pollen from sweet peas, tulips, and narcissus should be tried. Use a stronger sugar solution for the sweet pea pollen. Hollyhock and dandelion pollen are among the best for direct observation of form.

PRINTED MATTER: Select a piece of newspaper hav-

ing black print on it, and look at it with a power of 50 or 100 diameters. The letters are not black at all! Only streaks in the paper fibers appear colored, and most of these not very densely. Sometimes you will find printing whose characters look, under the microscope, as if they were made by printing a heavy border and filling in with ink less heavily applied, indicating that more ink was transferred from the edges of the type than the center. Typewritten matter shows the weave of the ribbon.

ROOT TIPS: If you are hunting for interesting root tips, as mentioned in another chapter, try the onion, corn, and hyacinth plants. These show their structures prominently. Wash carefully and mount in water. Look for the root cap that acts much like the devises used to push tunnels under rivers. Behind it are the growing point, hairs and, prominently visible, the spiral markings on the walls of the ducts.

SEAWEEDS: When you visit the seashore, by all means take your microscope along. You will scarcely find time for fishing or bathing, so numerous are the microscopic wonders you will find. Among these are the seaweeds that wash up on the beach. Their variety is infinite and their structure always fascinating. In addition to that, they harbor countless tiny forms of mcroscopic animal life.

SEEDS: The embryos of seeds already have been mentioned under that heading. Surface markings of the dandelion and other seeds are worth viewing, particularly those on the smaller seeds whose details are hidden from the normal eye. You will find that many seeds, like the dandelion, milkweed, elm, and maple have ingenious equipment for traveling on the winds;

that others, such as the water lily and iris, are equipped to float on water; and that still others, like the burdock and cocklebur, have hooks so they can cling to the fur of animals.

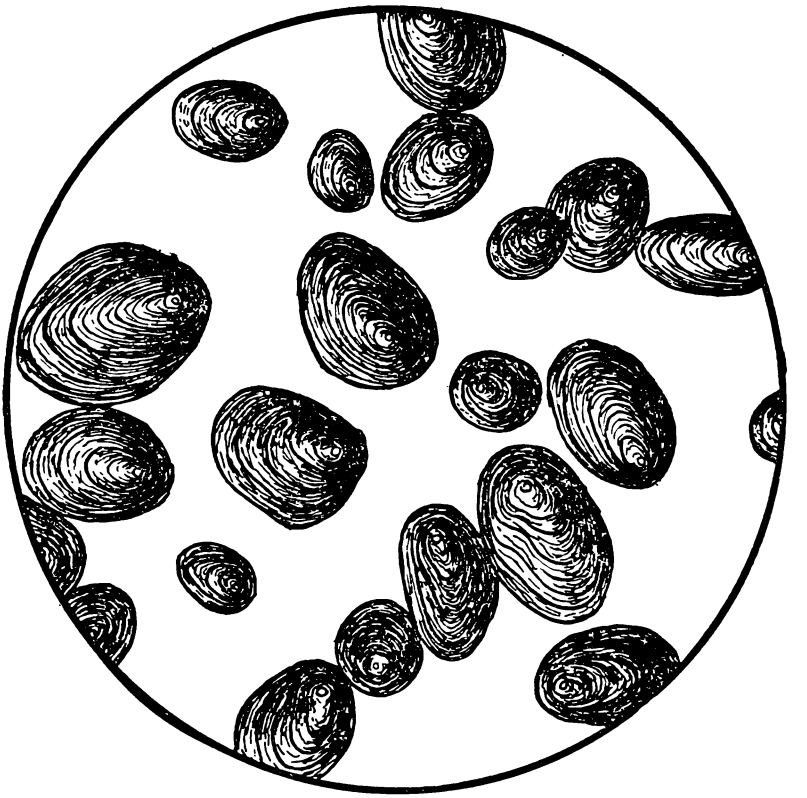
SPIROGYRA: Every student who studies botany in school meets this plant early in the course. You won't forget it easily, because the end-to-end cells are decorated with spiral green bands, like a house at Christmas time. You can make permanent mounts by fixing the plant in chrome-acetic acid, as described in another chapter, and then mounting in glycerin jelly in a cement-ringed cell.

SPONGES: You say you took a bath with a sponge? You didn't exactly do that, because you used only the sponge skeleton, a maze of horny fibers, as your microscope will reveal when you inspect a fragment of it. The material forming the sponge is called spongin. However, some sponge animals produce no skeleton at all, while others make skeletons that would not be very comfortable for bathing purposes because they are composed of sharp-pointed needles or spicules of silicon or lime.

STARCH: You can find starch in many shapes, which is fortunate because it makes microscopic identification of various plant and food material easy. Iodine stains starch blue. Inspect starch grains from as many sources as possible, such as corn seeds, oats, buckwheat, potatoes, tapioca, wheat, rice, and canna roots. You will be surprised at the variety of shapes. Generally you can obtain enough material for study by scraping the seed or root with a knife.

STEMS: Slice a plant stem into a thin section, and you have just about the most beautiful natural won-

der. You can enhance its beauty by applying some stain, such as methylene blue. Corn, water-lilies and



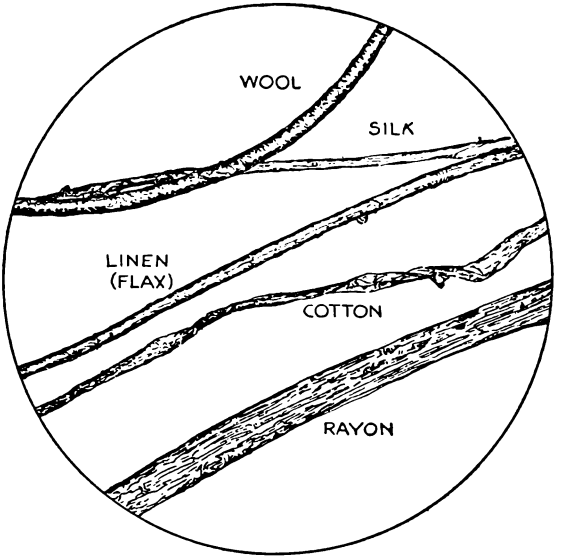
GRAINS OF POTATO STARCH

the Dutchman's Pipe vine provide interesting stem structures.

STOMATA: These are the breathing pores of plant leaves, the Wandering Jew, Aloe, and Iris being pro-

vided with interesting forms. See Leaves and Epidermis.

TEXTILE FIBERS: Of what is that new suit made? Yon can answer by magnifying the fibers. Wool, cotton, linen (flax), real silk, and artificial silk are the



commonest textile fibers. Select those that have not been dyed, and mount dry.

VOLVOX: This mystery of the microscopic world—it has not been settled definitely whether it is plant or animal—occurs in pools and ponds in the form of tiny green pinheads. You can make permanent mounts of Volvox by staining it with haematoxylin or other preparation and mounting it in balsam in cells deep

enough to prevent crushing of the delicate forms by the cover glass.

WATCHES: Bring from the junk box that old watch, for it contains several wonders. Under your microscope a tiny screw that looked to your naked eyes as if it had no thread becomes the size of a gallon jug. You marvel at the skill of the genius who made it. In a similar way, you can inspect other wonders of the watch. Now you know how the microscope is used in factories for checking tiny machinery parts.

WOOD CELLS IN PAPER: The paper on which this is printed once was a tree, or perhaps parts of a dozen trees. All cheap paper, such as that used for newspapers, books, and magazines, is made from wood. Consequently, your microscope will reveal characteristic wood cells interlaced to form the paper. To examine individual cells, tear some paper into small pieces and boil in lye solution (potassium or sodium hydroxide) until the fibers separate. Wash them to remove the lye, and then observe in water or dry. On some cells you will see characteristic wall markings like those that were visible in plant stems and roots. Linen and other rag papers show typical textile fibers. If you buy high-priced writing paper that is supposed to be linen, you can learn whether you were cheated or not, by inspecting the fibers.

CHAPTER VII

PRACTICAL USES OF THE MICROSCOPE

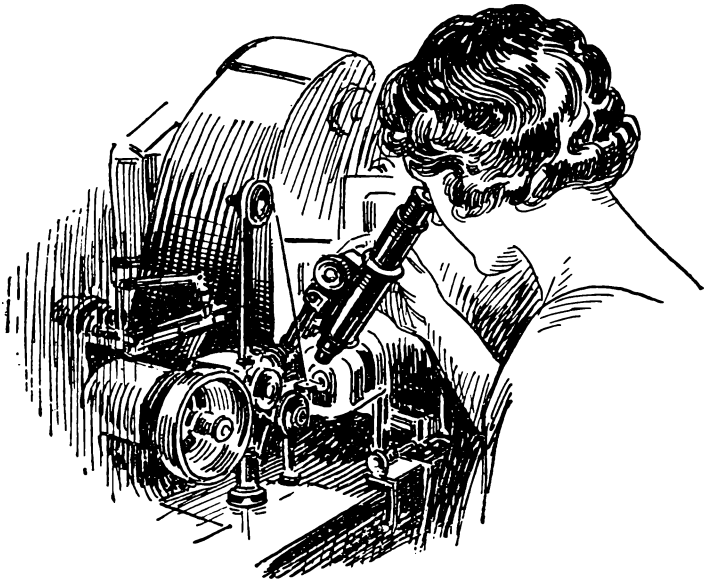
MENTION amateur microscopy to several persons who never experienced the thrills of touring in Microland, and one of the questions asked most frequently will be: "What are its advantages?"

It is not easy to enumerate all of the possible advantages because they are many and varied, since the boy or girl who gets a five-dollar microscope for a present may use it as a ladder to climb to the heights of fame by any of a thousand different routes.

If it had no other merits, the microscope would deserve its present popularity because it is one of the most powerful educational instruments ever devised. The microscopist who is so interested in his hobby that he gazes at everything he can get his hands on is absorbing, painlessly and pleasantly, more knowledge about the ways of Nature than he could gather by any other known means. A teacher can describe a Diatom until he is blue in the face, and not impart to his listeners one-half the information that a good microscope can furnish at a single glance.

The young microscopist should browse; he should look at anything and everything that holds the faintest promise of being interesting. Then, after he has roamed over the animal and vegetable and mineral kingdoms, and whatever other domains he can find, he

may decide to specialize. A few years of general browsing will provide a substantial background for future work in some specific phase of microscopy. For example, there are men who finally settled down to studying nothing but Diatoms. Others became authorities



THE MICROSCOPE IN INDUSTRY

on Protozoa. Still others gained fame in the field of photomicrography.

A photographer in an Eastern city found business dull, so he accepted a position as police photographer in another city. He became interested in questionable documents and learned how to employ microscopes to uncover details of typewritten and hand-written papers

and to detect forgeries. Eventually he became the document expert of the department, and was provided with a laboratory that included two microscopes built specially for the peculiar form of detective work involved.

Often microscopy as a hobby can be put to good use as an aid to some regular line of work. There is, for example, a maker of rotary files who raised tropical fish as a sideline. He became interested in microscopes when he learned that they would reveal scores of tiny animals that lived in his aquariums, but whose presence he had not suspected. Then he found that his microscope was not limited to water exploration, but could help him make better tools by revealing flaws developed in machining and heat-treating the steel.

The microscope is an entertainer of the first order. If you visited the 1933 Century of Progress Exposition at Chicago, you probably were spellbound for a considerable time by the attractions of the micro-vivarium in the Hall of Science. Vinegar eels, Paramoeciums, and other denizens of a stagnant-water drop entertained visitors by wriggling or dashing over an illuminated disk several feet in diameter. Microscopes set up as projectors were used to throw the images on wall screens.

With a micro-projector, constructed as described in this book, you can, in a like way, become something of a local entertainer, providing really interesting diversion at parties and similar gatherings. One man, at least, cashed in on his microscope by setting it up in a public park and then charging passersby a nickel each to look at the wonders he had arranged.

Then there is the ever-present chance to make an

important discovery with the microscope. Who knows but that you will be the first person to see a hitherto undiscovered inhabitant of the woodland pond? Of course, you will have to learn a great deal about the well-known forms of microscopic life before you will be able to recognize a discovery when you make it.

One of the most spectacular and important applications of the microscope is the capturing and conviction of criminals. The microscope can see and analyze clues that are invisible to the eyes of the keenest detective, so that the committing of a perfect crime is much more difficult today than it was in years past.

Starch is, you have learned, a substance easily recognized when submitted to high magnification. Furthermore, the various kinds of starch can be distinguished from each other. This fairly common feat of the microscope led to the conviction of a man for a crime that he at first denied. It was necessary to prove that he had been in a certain flour mill. Microscopic examination of the dust in his clothing and the mud on his shoes proved that particles of wheat starch were present in abundance. With this evidence, the police were able to prove him guilty.

Sometimes the victim of a murder grapples, before death, with the assailant. For that reason, well-equipped police departments look under the victim's fingernails for bits of hair, fibers from clothing, scales from skin, and other particles that might be identified as coming from the suspect. Conversely, similar matter found beneath the suspect's finger nails has led to conviction: the microscope showed conclusively that the skin, blood, and hair came from the victim.

In an Eastern city a man murdered, with a hammer,

a night watchman who caught him robbing a store. The police microanalyst was able to show that blood-stains on the hammer were the same as those on the accused man's clothing, with the result that the murderer was sentenced to 20 years in prison.

Almost every day a microscope, in the hands of an expert who probably began as an amateur, solves a major crime; but there are other equally important mysteries that it solves outside the annals of crime,—feats of magic that seldom are known beyond the walls of the laboratory.

As an example of the highest type of detective work performed by the microscope, there is the record of the Microanalytical Laboratory of the Food and Drug Administration, United States Department of Agriculture. As its name indicates, this laboratory is maintained for the sole purpose of analyzing things with the aid of the microscope.

The Food and Drug Administration, which has the job of keeping a watchful eye on the canned foods, imported foods, and every other form of edible material; and on all the drugs and cosmetics and patent medicines sold in this country, maintains branch laboratories in various important cities. There, trained microanalysts test samples of foods and drugs and other things coming under the Administration's observation. Usually the branch station is able to determine exactly what the samples contain, and measure the quantity of adulterants and poisons present. However, an occasional problem develops that cannot be solved by the field laboratory. It is then that the sample is sent to the place where few mysteries remain unsolved, the Microanalytical Laboratory at Washington.

The sample is turned over to scientists who are experts at answering the question, "What's in it?" The microanalyst must be a chemist, physicist, biologist, toxicologist, and a few other "ists" all in one; but above all he must have a photographic memory. When he sees, through a powerful microscope, a bit of vegetable matter, he must be able to tell at once from memory whether it is a mold filament, a shred from a plant stem, or what not.

Because absolute identification generally is made by comparing the unknown substance with known samples until a perfect match is obtained, the laboratory has an unusual museum. This takes the form of a many-drawered filing cabinet in which are hundreds of bottles containing specimens of every substance likely to be encountered in the analyses of foods, drugs, medicines, and cosmetics.

One day there arrived at the laboratory a bottle containing a dark-colored liquid. The microscope experts knew that it was supposed to cure diabetes, a disease for which science claims there is no absolute cure; and that it sold for $12 a pint; but they knew little more about it.

One of the experts put a drop of the liquid on a slide, dropped a cover glass over it, and looked at it through a microscope. After examining every part of the area under the cover glass, he was as puzzled as ever: no clue had been found. So he put some of the preparation into a centrifuge, whirled it at high speed for a time, and then stopped the machine. There was sludge in the bottom of the test tubes, solid matter driven out of the liquid by centrifugal force.

Under the microscope lens went some of the sludge.

Ah! Here was something the microscopist could get his teeth into. The irregular particles he could see were, without doubt, bits of plant tissue. But what plant? So, to the museum of samples went the analyst. By comparing the tissue on the microscope slide with that in some of the bottles, he eventually found the answer. The medicine was essentially nothing but an extract made by soaking or boiling the equisetum plant, commonly known as horse tail or scouring rush, in water. The Government, with this evidence, could take action against the preparation, which, it was maintained, was of no value whatever in the treatment of diabetes.

So important is the microscope in our present-day industrial life that it is found in the laboratories of every progressive steel mill, rubber factory, automobile company, and wherever else manufactured articles are produced with an effort to attain the best in quality.

Organizations and individuals are employing the microscope to test the quality of raw materials and manufactured items they buy, and thus make certain that they are not being cheated.

You, too, can use your microscope to determine whether or not the clothing and food and other things you purchase are what they are supposed to be. For example, you can tell whether a suit is all wool, or part wool and part cotton or something else. First, obtain samples of wool, linen, silk, rayon, and cotton fibers, samples whose identity you know positively. Study these with your microscope. Observe that the surface of a wool fiber is covered with scales; that cotton fibers are somewhat flattened and twisted; that linen, which is composed of the bast fibers from flax, has joints and markings characteristic of plant material; that rayon

or artificial silk fibers are like long, jointless rods, often with a surface scored with many fine lines; and that a real silk fiber is made up of two strands cemented together so that it looks as though it had a canal running along its center.

In a similar manner, playing the part of a micro-analyst, you can learn to identify numerous kinds of woods more certainly than the veteran craftsman who depends on general appearance alone; you can tell at a glance whether a sample of sweet butter contains salt that might be injurious to an ill person; you can learn to identify mold filaments that occur in spoiled food. In fact, there are a surprising number of ways in which the microscope can be of real service to you, just as it is of tremendously important service to industry and science.

A microscope may prove to be your key to fame and fortune; but if it does not, it is certain to entertain you in a way that nothing else can.

CHAPTER VIII

THE MAGIC OF LIGHT AND COLOR

THE most beautiful city or most fascinating forest would be a dismal failure as a tourist attraction if it could be visited only in darkness. The traveler would find little to interest him in the odors, sounds, and feel of the things that were there. It requires light to make traveling a pleasure.

In the microscopic world light and color rule. Before you can hope to see any of the wonders through your microscope, you must arrange for proper illumination. You will see and enjoy much color that is natural; but you will learn also to employ color as a tool that will enable you to observe details that otherwise would be indistinct or invisible.

The swinging mirror beneath the stage of your microscope was put there for the purpose of directing light through transparent specimens. Opaque objects which must be viewed by reflected light do not require the use of this mirror: some other arrangement must be made for lighting them.

The first requirement of good illumination is that the mirror and lenses of the microscope be perfectly clean. Use, for this purpose, fresh lens tissue. You can buy, for a few cents, a pad containing a great many sheets of the tissue. Use a fresh sheet each time you find it necessary to clean a lens, and then throw it

away. Wipe the lens gently with the paper; do not scour it. If the dirt does not come loose with this treatment, breathe gently upon the lens so as to produce a thin film of moisture, and then wipe it off with the paper. Particles of dirt on the upper surface of objective lenses, and wherever else the glass surface cannot be reached easily with tissue, can be lifted off with a clean camel-hair brush. Frequently the only thing you have to do to clean a lens is blow upon it gently. Use lens tissue or a brush as little as possible. If no lens paper is available, you can use an old, clean piece of soft linen, one that has been washed a number of times so that the fibers are soft.

Some microscope workers prefer daylight to artificial illumination because it does not produce false color values. They use the mirror to direct upon the specimen the light coming from a north sky or a white cloud. Daylight, however, generally is unreliable. When you want to explore the mysteries of a sea shell, the light is dull or night has overtaken you; and when you have a ticket to a baseball game, the illumination is absolutely perfect for microscopical work!

The almost universal use of electricity has put daylight into second place. This process has been speeded by the introduction of light filters and bulbs that produce artificial daylight. The more costly microscopes are equipped with these filters—little circles of blue glass that slip into grooves beneath the substage condensers. Another way of producing good imitation daylight is to arrange, in front of an electric lamp, a jar containing a weak solution of copper sulphate to which a few drops of ammonia water have been added. Still another way is to employ a standard daylight bulb,

which you can buy at any electric store. Finally, you can obtain pieces of blue glass that can be placed anywhere between the lamp and microscope.

You will enjoy making a microscope illuminator, although if you don't want to take time from your explorations of the subvisible wonderland, you can buy one of the numerous kinds that are on the market.

The simplest illuminator is the "tin-can lamp." Obtain a square can large enough to hold a 25- to 40-watt lamp and a screw-ring porcelain socket, and having a tight-fitting lid. In the center of the lid cut a hole and mount the socket. Insert the lamp and mark, on one side of the can, a point directly opposite the middle of the bulb. With this mark as a center, lay out a square opening as large as the width of the can will permit. Cut along the sides and bottom of the square, but not the top. Use a chisel or some other tool that will make a clean cut without tearing the surrounding metal. Bend the rectangular piece outward and up until it sticks out like the roof of a porch. With pliers, fold about ⅛-inch of the metal over so that rounded edges and corners are produced. This projecting roof prevents light from shining into your eyes when the illuminator is standing on the table in front of the microscope.

Around the top and bottom of the can, on each side and at the back, punch several holes for ventilation. A daylight bulb is excellent for use in the illuminator. You probably will find that better results are produced if a sheet of ground glass is mounted over the opening, to diffuse the light. Solder clips on the inside of the can to hold the glass.

For a more powerful source of illumination you can

use an arc lamp, or a 108-watt (6-volt, 18-ampere) microscope lamp. Either of these, used in conjunction with a condensing lens, is necessary for best results in making photomicrographs, but is not desirable for ordinary visual observations. You can employ, also, a photoflood lamp, either with or without a condenser.

There are two kinds of 108-watt lamps. One, using a ribbon filament and costing about six dollars, will be of little interest to you. The coil-filament type, selling for $1.80, will serve your purpose just as well. Because the lamps use but 6 volts, a transformer is necessary for stepping down voltage of the house-lighting circuit. Special transformers have been designed, but an illuminating engineer who specializes in miniature lamp applications suggests a 150-watt toy transformer having a 6-volt tap. You will be wise to have the output voltage checked to make sure that it is not too great. A suitable rheostat in series with the bulb will control its brilliancy.

Most of the wonders you are going to examine will be seen against a brightly illuminated field, the light passing through them into the objective of your microscope. You will find, before you have looked at many specimens, that various effects can be obtained by changing the intensity of the light, moving the mirror and by changing the color of the illumination. Beginners often make the mistake of using too much light. The illumination should be sufficient to reveal details of the object, but not bright enough to cause eyestrain. Incidentally, to reduce eyestrain further, learn to keep both eyes open, and shift from one eye to the other, so that both are used an equal amount. Constant use of only one eye over long periods may result in injury

to vision that is difficult to correct. Changing from one eye to the other eliminates this danger. In fact, some microscopists claim that vision actually can be improved by using a microscope, providing the eyes are not unduly strained.

More than two and one-half centuries ago, Antony Leeuwenhoek, a Dutch experimenter, amazed his friends by telling them about little "beasties" that swarmed in a drop of stagnant water or were present in the scrapings from his teeth. He had seen them with simple, single-lensed microscopes of his own construction. But if he astonished the friends he permitted to peer through his magic lenses, he amazed even more the naturalists who have followed him. He described and made drawings of creatures so small that, even today, they can be seen distinctly only with a microscope magnifying several hundred diameters! Leeuwenhoek's simple lenses, the best of them, were said to magnify up to 270 diameters. But he described things that cannot be seen distinctly at that magnification!

The only logical theory offered to explain how he accomplished such exact work with the crude microscopes he made is that he stumbled upon some system of dark-field illumination. This method, in which the object is seen brilliantly lighted against a dark background, reveals details that cannot be seen with bright-field arrangements.

Although true dark-field illumination requires a substage condenser with a special stop, you can obtain satisfactory dark-field results with a microscope having only a substage mirror. One way is to tilt the mirror until only the edge of the light beam is reflected through the object. The light rays, striking the object

at an angle but missing the lens, produce the desired effect. Another way is to swing the mirror to one side, if its mounting permits such adjustment, so that the light beam is projected obliquely through the object but does not enter the objective lens directly. Still another way of producing dark-field effects is to adjust the mirror for bright-field work, and then introduce your finger or a cardboard disk into the light beam, preferably between mirror and stage, so that part of the beam is cut off.

The opaque seeds of many plants make interesting objects for study, but they are not transparent and therefore must be inspected by light falling upon them from above. If you have an arc lamp or a concentrated-filament incandescent lamp equipped with a condensing lens, you can focus a small, bright spot of light on the object; or you can arrange a reading glass or magnifying mirror on a stand so that it will concentrate light from almost any source on the specimen. Swing the substage mirror so that it does not direct light upward, or place a piece of dark paper beneath the slide. Some microscopes for amateurs have mirrors that can be attached above the stage, for illuminating opaque objects.

When using an arc or high-powered Mazda lamp for illuminating any kind of microscopic specimen, the heat developed will cause damage if permitted to act for more than a brief period of time. To eliminate this heat, use a water cell. You can make one by bending a piece of rubber tubing, having an outside diameter of ½-inch or more, into the form of a U, and clamping it, open side up, between two sheets of glass, preferably plate glass. Pour water into the cavity formed

by the tube and glass, and mount the cell so that the light beam must pass through the water in order to enter the microscope. Keep the glass and water clean.

With a microscope that magnifies up to 75 diameters and that cost ten dollars at boom-time prices, one observer made an interesting discovery. He was playing with a set of three-color photographic or "A, B, C" filters, inserting them into the light beam in order to determine how they affected the color of the butterfly-wing scales he was examining. He found, to his surprise, that the filters affected not only the color of the specimen but also the focus of the microscope.

First he focused as sharply as possible by the light from an electric lamp. Then, upon inserting either of the filters, the image could be made sharper by refocusing. A little experimenting showed that, when the red or A filter was used, the microscope had to be racked upward, the effective focus of the lenses being greater. With the green B filter, the lens had to be moved closer to the object, and with the blue C filter, closer still.

The explanation is that lenses used in microscopes of low or moderate price are not corrected for colors. Even the achromatic lenses generally used in high-grade instruments are corrected for but two colors. Such lenses are visually sharp for most purposes, in white light; but the use of color screens often will improve their images. The making of photomicrographs with achromatic lenses, as well as the cheaper ones, requires the use of color filters. The highest grade lenses are apochromats, costing several times as much as other types because they are corrected for three colors.

All of which indicates that you can sharpen the image produced by your microscope by introducing into the light beam color filters that absorb most of the light rays that would not focus sharply. These filters can be of various kinds. You can employ pieces of colored cellophane, colored glass, or the transparent material used to give color to store windows or theater spotlight beams. Another way is to bleach old photographic plates or films with potassium ferricyanide solution, or with dilute tincture of iodine followed by a bath in photographic hypo fixing solution to remove the iodine stain; and then color the gelatin with dye.

Better than any of these is a filter made by inserting special filter gelatin between two sheets of glass and binding the edges with lantern-slide tape. The Wratten photographic and microscopic filters, of which there are numerous colors, can be obtained in gelatin form for about 10 cents per square inch, in pieces not smaller than 4 square inches. You will find the A, B, C, G and perhaps the 45A filters useful. The first four can be used for photography, while the last one is intended for visual work.

It is a good idea to make the filters of a uniform size, say 2 x 2 inches, and then build a box, with slotted sides, to keep them in; and an adjustable holder for use with the microscope. Simply set it in front of the microscope, insert filter and adjust the movable arm until all the light reaching the mirror is colored.

Many of the wonders of nature can be viewed through the microscope in their natural state. You can, for instance, tear the wing from a mosquito, place it on a glass slide, drop a cover glass over it and be examining the tiny scales, all in less than a minute.

Sooner or later, however, you will find that it is not so easy to see all of Microland's sights without making some special preparations. Some of these preparations have to do with color. You apply a stain, sometimes more than one stain, in order to bring out details.

Iodine is one of the stains you will find helpful. Take one part tincture of iodine, which is made by dissolving solid iodine crystals in alcohol, and dilute it with about 5 parts of either alcohol or water. Keep this in a bottle that has a tight-fitting cork, preferably one that screws on and is equipped with a dropper. Iodine stains various substances different colors. It will impart a brown or yellowish color to some plant substances such as cell nuclei. When applied to starch, it turns the starch granules blue. If you spill iodine on your clothes or fingers, you can remove the stain with photographer's hypo.

Another useful stain, one that is employed widely in medical and other laboratories for staining animal tissues and for coloring vegetable material, is eosin. It produces a pink or red color. You can purchase this dye in tablet form or as a powder. It is dissolved in water or alcohol to form the staining solution.

Methylene blue is another popular stain. Loeffler's solution, used widely for staining bacteria, also will color many of the objects you will be inspecting with your microscope. If you cannot buy Loeffler's stain already prepared, from your local druggist, you can have him mix it according to the following formula:

Methylene blue, saturated solution in alcohol.. 30cc.
Water to which has been added two drops of
10% potassium hydroxide solution.....100cc.

Carmine is an easy stain to prepare. Place some of the red powder in water, stir and add ammonia water until all of the carmine has gone into solution. Filter through paper and then evaporate the water with gentle heat until a solid deposit is left. When again dissolved in water, this ammoniacal carmine makes a staining solution that will keep for years. There are other carmine stains, but this is one of the easiest to prepare. Carmine generally stains materials that contain nitrogen. For example, it will color the nucleus of dead plant cells a deep red, and the protoplasm a lighter color, while most of the carmine staining compounds do not readily color starch, cellulose and other materials containing no nitrogen.

Haematoxylin is another stain that you ought to have in your collection, the Delafield formula being widely used. Its proper preparation, however, is somewhat complicated, so that you will be wise to have your druggist do the job, or to buy the stain ready-made from some supply house.

Only a few of the scores of available coloring agents have been mentioned. The subject of biological stains and their uses is one that would require a separate book to cover completely. The amateur will find those listed here useful and readily procured.

There are various methods of applying stains to a microscopic specimen. The material can be suspended in the solution long enough to absorb the color. Another way is to place the specimen on a slide and dry it, so that it forms a thin film; then flood with stain, wash and dry again, and mount in balsam or similar material. For yeast plants or other material placed temporarily on a slide in water, you can drop a little

of the stain on the slide so that it covers the specimen, before putting the cover glass into place.

Now for a little adventure with color:

Cut a piece from a raw Irish potato and, with your scalpel, scrape the freshly cut surface until you have obtained a drop of cloudy liquid. Smear this on a slide and drop a cover glass over it. Through the microscope, you see hundreds of rounded grains. On most of them, you can see concentric rings or layers, and near one end a little dot or "hilum" that looks like a hollow place. These are grains of potato starch.

Now lift the cover glass and, with a dropper, introduce a little dilute iodine solution. Very rapidly the grains become blue in color, and some of the dots appear more prominent. The iodine has reacted with the starch to produce the characteristic color. This reaction is used as a quick test for starch. Now place, in front of your microscope mirror, a blue filter. The entire field becomes blue, and the starch grains are, if anything, less distinct than they were with white light. Perhaps you can make them appear a little sharper by refocusing. Now substitute a red filter for the blue one. A surprising difference! The blue starch grains have absorbed the red light so that they appear dark, or black, while the surrounding field is a bright red. In other words, the contrast between the object and its background has been increased—a matter of great importance in the making of photomicrographs.

This experiment has demonstrated how color can be used by the microscopist to make his trip through Wonderland more fascinating. It also has proved that a potato, which outwardly is no more attractive than the onion, really is a thing of beauty.

CHAPTER IX

ACCESSORIES FROM ODDS AND ENDS

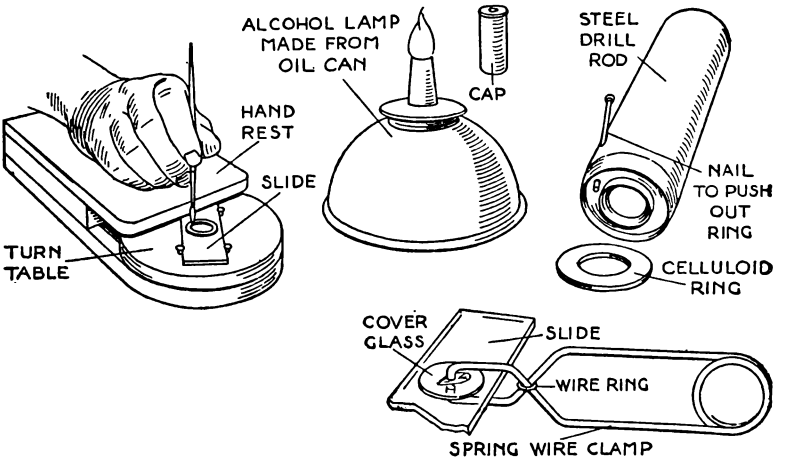
ONE reason why microscopy is such a fascinating hobby is that it can be expanded to cover numerous other activities. For example, while the microscope is converting commonplace objects into works of art, you can become a craftsman and transform odds and ends from the junk box into accessory equipment that will make your micro-laboratory really professional in appearance and resources. While a few power-driven tools, such as those usually found in the home workshop, will be helpful, you can make by hand any of the items described in this chapter.

An Alcohol Lamp

A source of clean, intense heat is necessary in any kind of laboratory or workshop. If you have a gas connection, you can use a Bunsen burner. Another arrangement consists of an acetylene tank with a Bunsen or similar burner attached. But the simplest of all heating devices is an alcohol lamp, one that burns wood alcohol or denatured ethyl alcohol for fuel.

To make a rugged and efficient alcohol lamp, procure an oil can of the type generally used in shops, one having a diameter at the base of 2 to 3 inches. With a file or hack saw cut the spout in two about an inch from the threaded end, and discard the upper section.

Force through the remaining spout section enough string to fill it completely. Let the string project from the threaded end far enough to reach the bottom of the can when the spout is in place, with one or two inches to spare. Trim the outer ends of the string evenly, about ⅛-inch from the cut end of the spout.

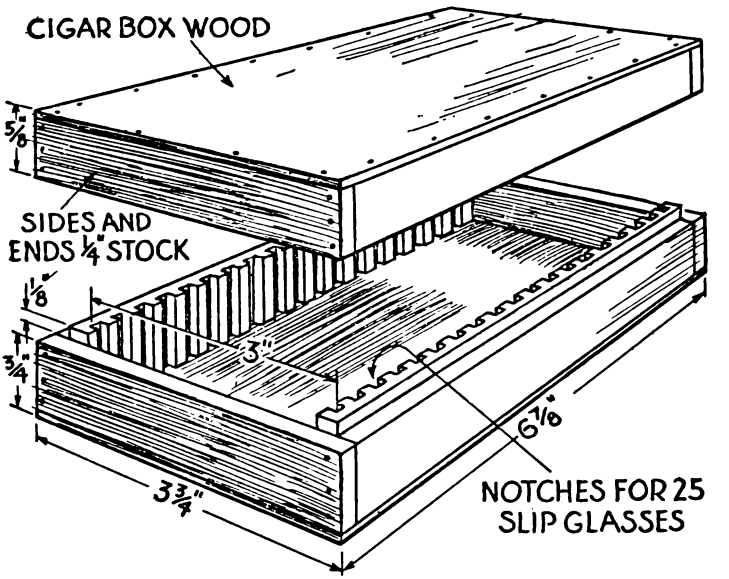


Procure an empty cartridge or some other cover that will fit over the spout and prevent evaporation of alcohol, and your lamp is complete. You will have to feed the wick through with a pair of tweezers or pliers, to make up for what is burned away.

Slide Boxes and Cases

Standardize your slides by using only the 1 x 3-inch size. Then you can construct boxes or drawers for holding them in neat rows, where they can be found instantly and where they are safe from damage.

Make the boxes from ¾ to 1⅛-inch deep, measured inside, the exact depth depending somewhat on the type of lid used. If there is to be but one row of slides, the inside width should be 2¾-inch. This allows for notches or grooves, running vertically and parallel, each about 3/32-inch wide and slightly more than ⅛-



inch deep, and spaced on 3/16 to ¼-inch centers, into which the ends of the slides slip. Be careful to get the grooves in the two sides directly opposed, so that the slides will be held straight.

You can cut the grooves with a hand saw and miter box, or with a circular saw if one is available. Corners and bottom edges of the box can be fastened with any kind of joint, although miter joints for the corners and

a dado groove for receiving the bottom make the best appearance. The lid should fit as tightly as possible, to keep dust out. Grooves should be numbered and an index provided, so that slides can be kept in their proper places. This will save much time and make loss of a slide immediately evident.

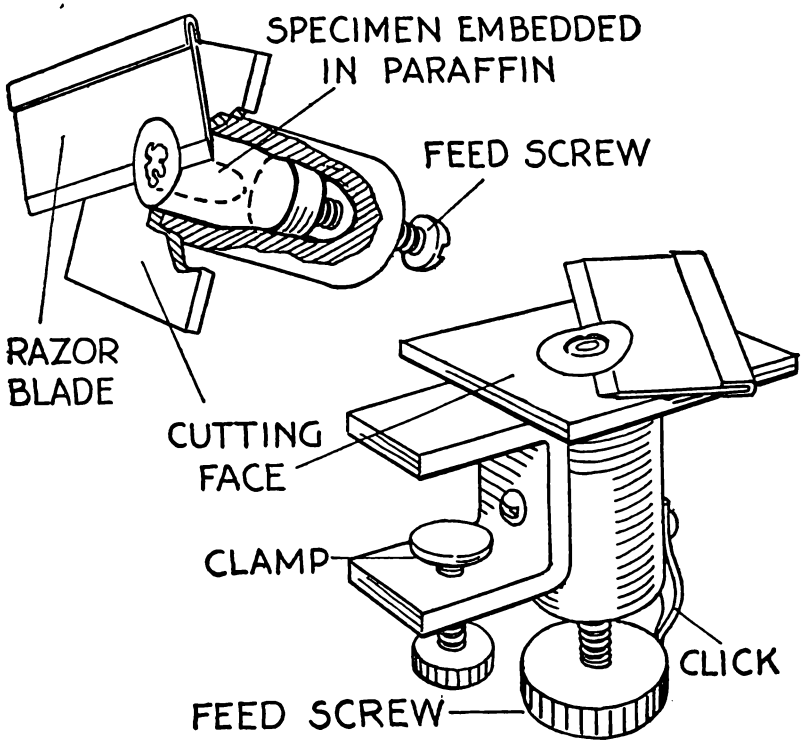
With the usual spacing of ¼-inch or so, you will find it difficult to read labels on the slides if they all are placed uniformly on the right-hand or left-hand ends. By alternating the labels, so that every other slide has its label on the right, you can read each label through the clear portion of the slide in front of it, thus doubling the effective spacing and making the finding of specimens easier.

Microscopist's Slicing Machines

A microtome performs the same function as the machine that slices butcher-shop bologna into thin pieces, except that it is much more delicate. A piece of plant stem, cross section of an insect, or a bit of animal tissue should have a thickness considerably less than $\frac{1}{1000}$ of an inch, when it is to be mounted as a microscope specimen. To cut such thin slices by hand requires much practice, considerable native skill, and a lot of luck. Why bother with guesswork when you can make, without much trouble, a gadget that will enable you to cut slices so thin that they are almost transparent?

A hand microtome consists of a 1¼- to 2-inch length of ⅜-inch tubing to which is soldered a flat plate, and in the other end of which is a plug carrying a fine-threaded screw that acts against a plunger. The specimen to be cut is embedded in paraffin or otherwise held

rigidly inside the tube where it can be forced outward a minute fraction of an inch at a time by a turn or partial turn of the feed screw. Slices are made by drawing a sharp razor blade across the flat plate.



A microtome of slightly more elaborate design can be built along similar lines, and provided with a C-shaped clamp with which to attach it to the edge of a table. Instead of having an ordinary bolt for feeding the plug forward, it is equipped with a screw having

a large, knurled head. A piece of spring wire or strip rests against the knurled head, forming a clicking device that will enable you to judge the amount of feed. You can calibrate the screw so that you know just how many clicks to use for a specimen of given thickness.

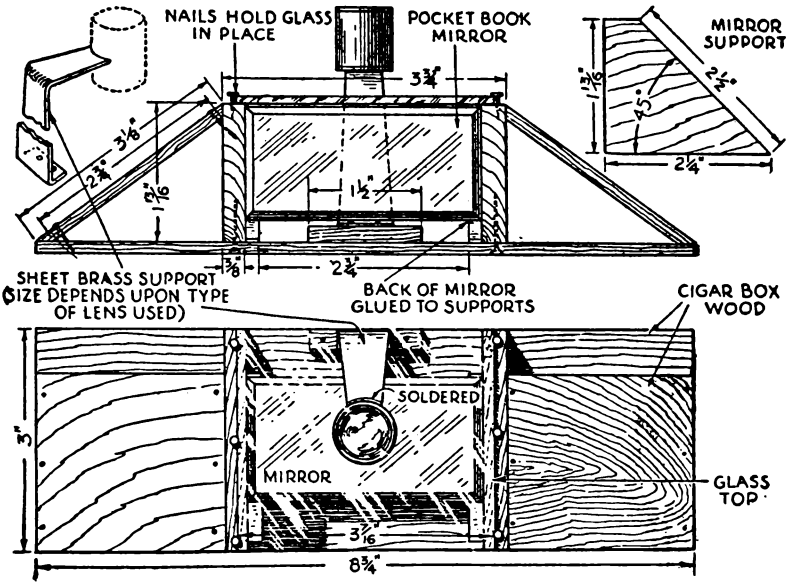
When soft specimens are mounted in paraffin, the block can be cast in the microtome well, or made of a size that will fit snugly. For cutting plant-stem sections, you can wedge the stems in place with pieces of dry elder pith or with wood splints. Another way of holding stems is to provide a set screw that projects into the well and against the specimen. For small specimens in paraffin, you can make a second brass plug that fits snugly inside the tube, and mount the piece of paraffin on the upper end by warming the wax until the surface is almost liquid, and pressing it against the metal.

An Operating Table

At the stage where the microscopist must become a surgeon, removing the organs of flies, crickets, and the like, and arranging them on a slide, he needs an operating table. In catalogs of scientific supply houses, you will find this under the heading "Dissecting microscopes." To make such an operating table is a simple matter.

Obtain a magnifying lens of good quality. One rated at about 7-power will be satisfactory. Procure also a small mirror of the type sold at ten-cent stores for use in women's handbags, a piece of clear glass measuring about 3 x 3½-inches, cigar box wood, small brads, glue, and a piece of stiff sheet brass. Construction of

the dissecting microscope and dimensions of important parts are made clear by the illustrations. The only important dimension is governed by the focal length of the lens. Be sure that the length of the brass mounting arm is such that an object resting on the glass top



will be in focus. You will be wise to mount the lens so that it can be adjusted up and down. One way is to use, instead of a brass strip, a ¼- or ⅜-inch rod, and a metal block drilled to slide over the rod and equipped with a setscrew. Fasten the lens to the block.

It is customary to mount the mirrors of dissecting microscopes rigidly at an angle of 45 degrees in relation to the glass top. Sometimes a more flexible

arrangement would be of advantage. You can, if you desire, design the mirror so that it can be tilted up or down. A frame around the mirror, hinged at the back and provided with some kind of locking mechanism, would serve the purpose.

A Holder for Color Filters

Construction of an adjustable holder for color filters is simple if you have the ordinary assortment of tools at hand. The holder consists of a slotted wood frame accommodating three filters, a base, and a means of adjusting the position of the frame to height and angle of tilt.

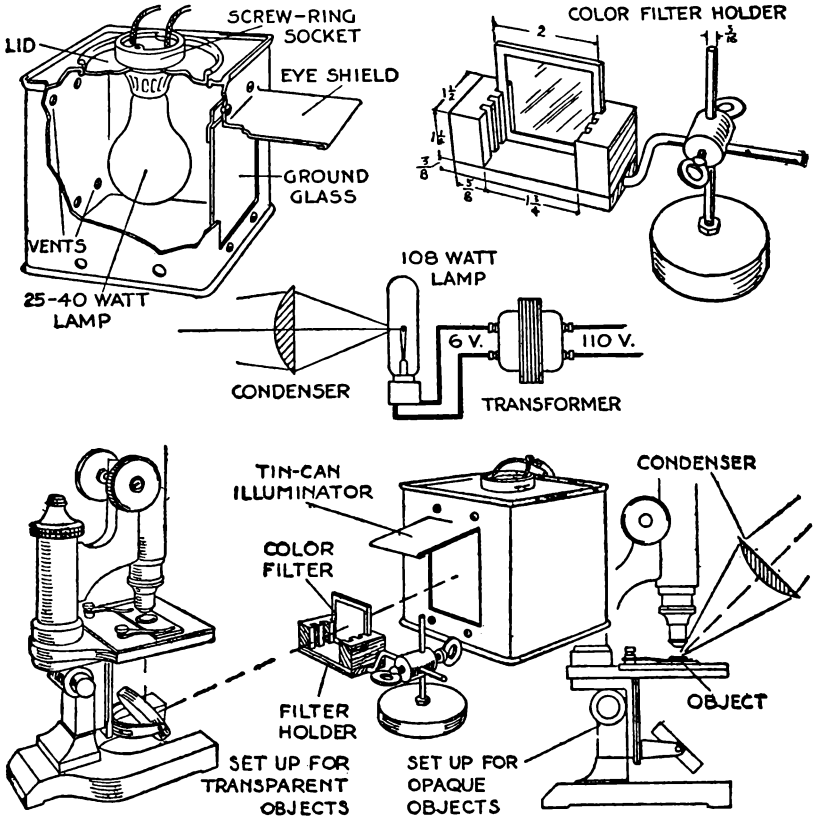
Walnut or maple wood is excellent for the frame. Cut three pieces to form a three-sided frame of a size about ¼-inch smaller than the diameters of the filters. In the two vertical side pieces, cut three parallel grooves each slightly more than ⅛-inch deep and wide enough to permit the filters to slide into them easily. Be sure that opposite grooves are lined up squarely.

Drill a hole in the bottom piece, parallel to the lower edges of the filters, and insert a 5-inch length of brass rod. The hole should be so small that the rod must be forced into it.

To make the base, mount a straight rod 5 inches long in a block or disk of metal or wood. The connector between the two rods is made of brass, or even maple or birch wood. Drill two holes at right angles to each other, to receive the rods with a snug, sliding fit. Then, at right angles to these holes, drill two more holes and tap them for setscrews. Ordinary stove bolts with washers soldered in their slotted heads make easily turned setscrews. By loosening either one or other of

the screws, the filter frame can be moved up or down, in or out, or swung through any angle.

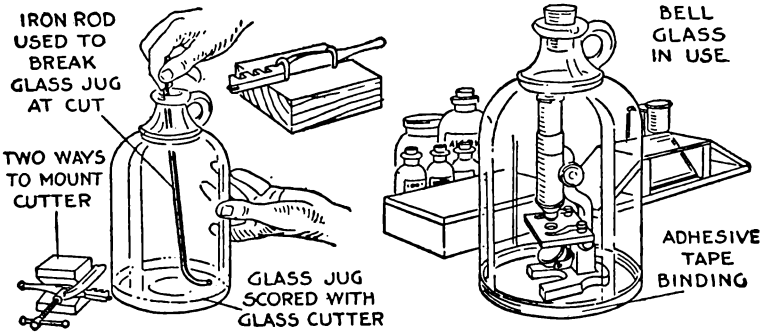
This type of mounting, incidentally, can be adapted



for use with any kind of illuminator, reading glass, condensing lens, or other instrument whose position must be adjusted frequently.

To Make a Bell Jar

In research and school laboratories it is customary to use glass bell jars to protect microscopes and other delicate instruments from dust. Such jars are, as their name indicates, shaped somewhat like a bell, having a knob at the top for lifting. They cost several dollars apiece.



For a few cents you can make a jar that will keep out dust just as well as one you might buy for five dollars. Your druggist will sell you an empty glass jug or bottle for a dime or two. For most amateur microscopes, the one-gallon size is sufficiently large. Select a jug that has smooth sides, not pebbled as are some soft-drink syrup containers. It matters little whether the glass is clear or colored, provided you can distinguish objects through it.

Clean the jar thoroughly and wipe it dry. With a good glass cutter, scribe a line around the outside, about ½ inch above the bottom. This is easy if you clamp the glass cutter to a block of wood about ½

inch thick, and rest it on a table beside the jar. Rotate the jar against the cutter wheel.

Get a piece of ¼-inch iron rod 5 or 6 inches longer than the height of the jar, and at a point 1 inch from one end, make a right-angled bend. With this rod as a hammer, tap gently around the inside of the jar, directly opposite the line scribed with the glass cutter. With surprising ease, you can cause the cut to extend completely through the glass, and the bottom to drop off. Of course, you may break a jar now and then because of some hidden flaw in the glass or in your technique.

Finally, bind the edge, which probably will be sharp and somewhat jagged, with two layers of adhesive tape, insert a cork into the neck, and your bell jar is ready for use. A jug is preferable to a bottle for making a jar because it has a convenient handle.

Slide-Maker's Spinning Wheel

At times the maker of microscope slides may become a spinner. When a thick specimen is to be mounted, a cell must be constructed for it, so that the cover glass will be separated a sufficient distance from the slide. One way of doing this is to apply shellac to form a ring, repeating with as many coats as necessary to make the cell of sufficient depth.

Building up a ring freehand is a clumsy operation that seldom produces neat results. With a spinning wheel, perfect rings can be made easily and quickly.

There are various spinning-machine forms, but the one shown on page 129 will produce perfect cells. It is made from four pieces of wood, a flat-headed wood screw, a washer, and several small nails.

Cut a 4-inch circle from wood ½ inch thick, three-ply veneer being the best material to use. In the exact center drill a hole and countersink it for the head of the wood screw. The screw should fit snugly in the hole. Lay the wheel so that its edge is even with the end and two sides of a piece of wood measuring ½ x 4 x 8½ inches. With a pencil, mark around the half of the wheel nearest the end; and then round the end to conform with the wheel. Mount the wheel with the wood screw, placing the washer beneath it so that it will turn easily. Of the two remaining wood pieces, one is a block 4 inches square and ⅞ to 1 inch thick, and the other is a piece measuring about ⅜ x 4 x 5½ inches. The block acts as a support for the ⅜ inch piece which projects over the wheel to form a hand rest. With a pencil, mark several concentric rings on the wheel, encircling the screw. Lay a 1- x 3-inch slide on the wheel, center it over the screw head, and drive several old phonograph needles or headless nails along the sides and ends of the slide, so that other slides, dropped into the enclosure formed by the nails, will be centered automatically. Perhaps a better way is to make a slide holder from sheet metal and fasten it on the wheel. Wood parts of the spinning machine should be finished with shellac.

To spin a cell, dip a slender, round brush into the shellac or other preparation being used, start the wheel spinning, and hold the brush against the glass in such position that a ring is formed. The diameter of the ring should be such that a circular cover glass laid upon it will extend to its center line. If the shellac is applied with sufficient care the cover glass will be sealed to the slide neatly and permanently.

A Substitute for Shellac Cell

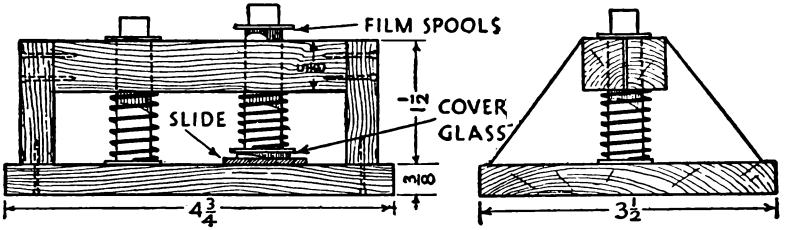
A quick way of mounting thick specimens is to cement a celluloid or paper ring to the slide, place in the enclosure thus formed the object and mounting medium, and then fasten the cover glass in place over the ring. For extremely thick objects, rings can be obtained or made by cutting sections from tubes.

When a metal-working lathe is available, you can turn out in a few minutes a tool that will cut as many paper or celluloid rings as you desire. Any machine shop can make the tool. It consists of a piece of shafting with two ring-shaped cutting edges turned on one end. The outer ring is of a diameter slightly greater than the cover glass you are to use. The inner one has a diameter about $\frac{1}{8}$ or $\frac{3}{16}$ inch less. If the rings and central disks are inclined to stick between the cutting edges, holes can be drilled and punches used to force them out. To use the tool, set the cutting end on the material to be cut and strike the other end with a hammer. The tool retains its sharpness for a long time without special hardening.

Clamp for Cover Glasses

Cover glasses cemented in place with balsam sometimes persist in coming loose at the corners or edges or slipping to one side. This can be prevented by use of a simple clamp. One is made by bending springy wire into a form resembling a laboratory test-tube holder and equipping the ends with cork pads. The spring tension should not be great or the cover glass might be cracked.

Another clamp is somewhat more elaborate. It consists of one or more spring plungers arranged so that they can press gently but evenly on the cover glass while the slide rests on the bed of the clamp. Certain types of photographic roll-film spools can be used as



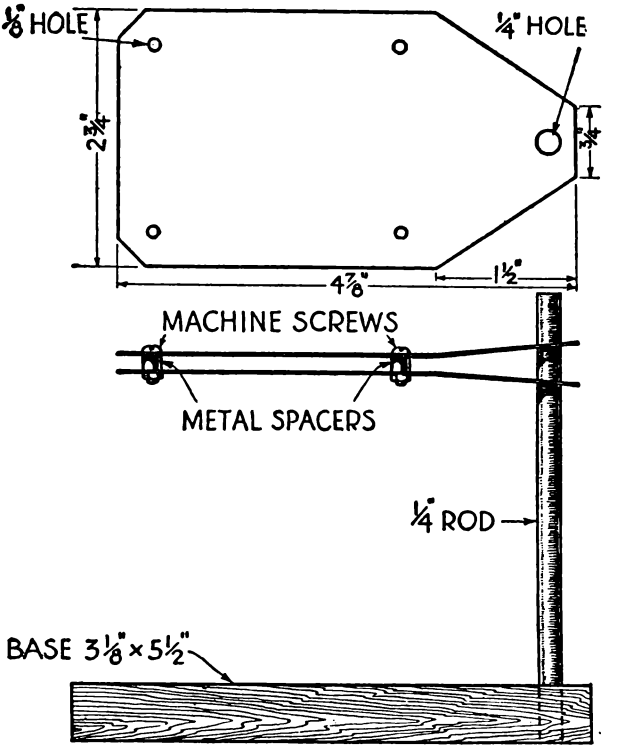
plungers. Various popular small cameras employ spools that are suitable. In placing a slide in the clamp, be careful not let the spring drive the plunger against the cover glass suddenly.

Handy Warming Stand

In drying specimens, evaporating small quantities of liquids, and mounting with balsam or glycerin jelly, a means of applying gentle heat safely is necessary. One of the most useful gadgets for doing this is a warming stand of simple construction.

The stand consists of a double shelf of sheet copper attached to an upright in such a way that it can be adjusted for height. A Bunsen burner or alcohol lamp placed beneath the shelf heats the lower sheet of metal directly. This in turn heats the upper surface evenly and not too severely.

The two plates are bent apart slightly at their tapered ends so that, when squeezed together until the



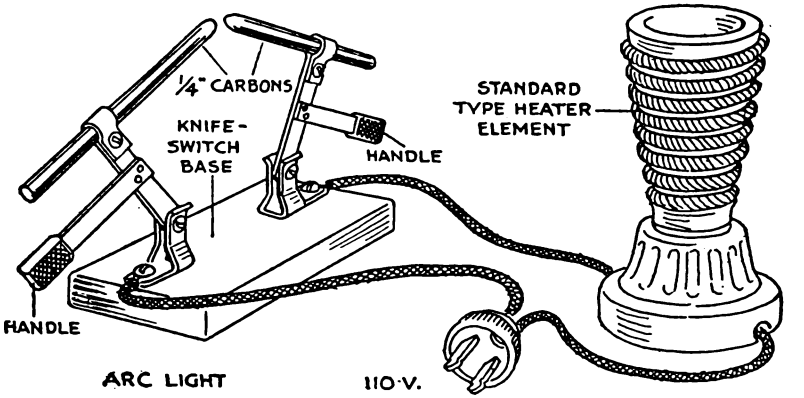
¼-inch rod will pass through the two holes and then released, they will grip the upright firmly.

Make Your Own Arc Lamp

An arc lamp is one of the most economical forms of high-intensity illumination that you can use in conjunction with your microscope. Although seldom required for direct observations, it is in some ways ideal for photomicrography and for projection of micro-

scope images on a screen. Construction of an arc lamp is not difficult, and does not involve the outlay of much money.

For an arc lamp that gets its power from the house-lighting system, a resistance is necessary. You can make a resistance unit suitable for operating a single arc lamp on a 110-volt circuit by connecting two porce-



lain sockets parallel with each other, and screwing into them two standard 550-watt electric heater elements; or using a single socket with a 1,000-watt element. This resistance unit is then connected in series with the arc lamp. For safety, install some kind of guard around the resistance units, for they become red-hot. A rectangular box made from 4-mesh screen is excellent.

The arc lamp proper consists of two $\frac{3}{16}$- or $\frac{1}{4}$-inch white-flame carbons mounted so that their tips can be brought together and then separated a fraction of an inch. There are countless ways of doing this.

Every arc lamp should be shielded so that its rays cannot shine directly into the eyes of the operator. For this purpose, a sheet-metal housing, large enough to clear the carbons and other electrical parts, should be installed. This housing can be equipped with a condenser lens mounted in an adjustable tube, for throwing a concentrated image of the arc on a microscope mirror or specimen.

To make an arc similar to that illustrated, obtain two single-pole, single-throw knife switches having porcelain bases. They will cost from 10 to 25 cents each. Remove the knife blade from one switch and mount it on the other in place of the pronged clip. Thus you have a switch with two blades. Remove the insulating handles from the metal strips, and attach in their places some kind of clamps that will hold the carbon rods rigidly. Moderate-sized storage-battery clips can be used, being held in place by the screw provided for attaching to wires; or you can make simple metal straps from sheet copper and small bolts in your own laboratory.

At a point on each blade about half way between the carbon clip and the base pivot, drill one or two holes and fasten, with bolts or rivets, stiff metal strips whose outer ends are equipped with insulators. Wooden grips will do. If you have two more knife-switch blades equipped with insulating handles, they will serve nicely. These insulated, projecting arms are used for starting and adjusting the arc.

Connect one wire from the supply line to one of the switch-blade terminals. Connect the other supply wire to one side of the resistance unit, and then run a wire from the other terminal of the resistance to the remain-

ing switch-blade terminal. Your arc lamp is complete, except for installing in a housing of some sort.

The drawing of the micro-projector shows another and simpler form of arc lamp that you can build, together with a sheet-metal housing equipped with a red glass window through which you can inspect the arc.

A Portable Laboratory

Whether you travel or not, a microscope kit will prove a handy addition to your collection of equipment. At home, you can use it for holding slides, dissecting instruments, reagent bottles, and specimen jars. You can keep in it your microscope, hand microtome, electric illuminator, and similar articles. The lid or door of the kit should be dust-proof, so that the contents will be protected.

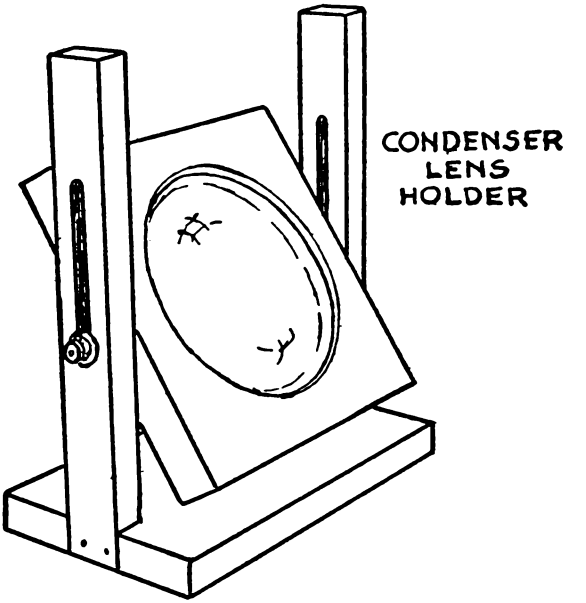
To make a kit, build or otherwise obtain a box of whatever size you think sufficient and convenient. The opening should be at the side. In one end of the box install several drawers. One should have slotted sides for holding 1- x 3-inch slides. Another should be partitioned off for holding small screw-top bottles in which you can place specimens. There should be a few bottles equipped with dropper corks, for holding stains, alcohol, xylol, etc. Another drawer will hold dissecting instruments. Then there should be one or two drawers for odds and ends.

The nest of drawers need not take up much room, not much more than a space measuring about 7 x 7 x 8 inches. The remainder of the box can be equipped with clips for holding the microscope, microtome, and illuminator. There should be a note pad and pencil. If the lid is mounted so that it can be separated entirely from

the box, instead of being merely swung outward on hinges, it can be used as a writing or drawing board. The outside finish should be attractive. A handle for carrying is mounted on the top.

Condenser Lens Holder

For photomicrography, some kind of condensing lens is essential, and for other work with the microscope it will be found convenient. You can purchase,



for less than two dollars, a plano-convex lens 4½ inches in diameter and having a focal length of about 4½ inches. This lens can be handled conveniently only when mounted. A satisfactory stand for it can be built from scraps of lumber.

Obtain a square piece of wood about ½ inch larger all around than the lens diameter, and ¾ to 1 inch thick. Cut a circular opening in the center slightly smaller than the lens, and then enlarge the size for a depth slightly more than half the thickness of the board, so that the lens will drop in and rest against the remaining ledge. Fasten the lens in place with three or four brads carefully driven into the wood.

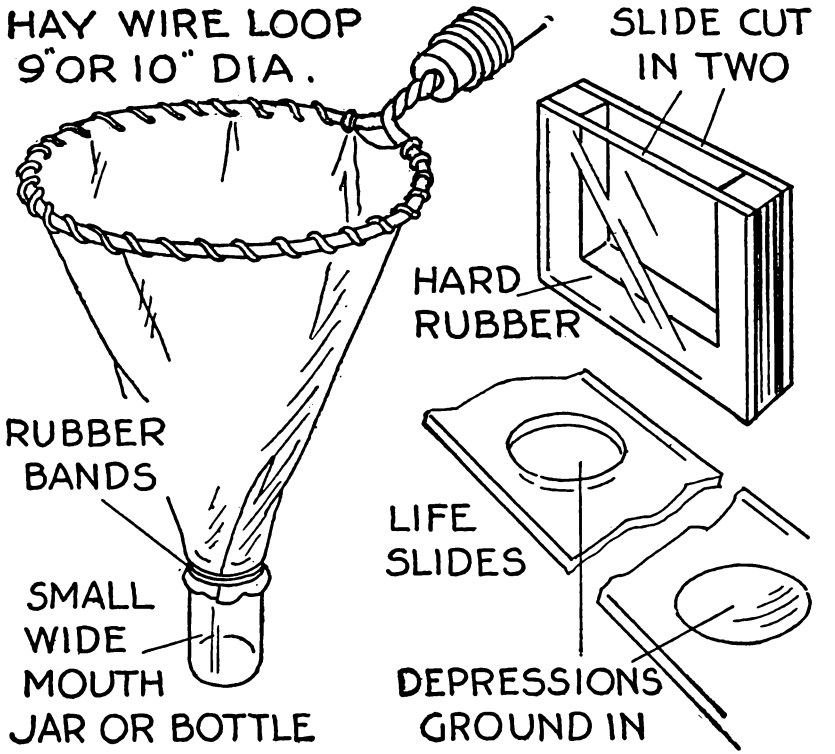
The square block is supported by two slotted uprights fastened to a rectangular base. In the centers of two opposite edges of the lens block, drill two holes and force bolts into them. Cut off the heads of the bolts, leaving enough of the threaded portions projecting to extend through the slots in the uprights. Put a washer and wing or knurled nut on each bolt, so that the lens can be locked at any height within the limits of the slots, and at any angle. The wood should be painted or lacquered, preferably some dark color.

Collecting Net for Water Specimens

Although you can dredge microscopic wonders from the bottom of a pond or stream with an old tomato can or a bottle tied to a string, you will find it much more satisfactory to employ a collecting net similar to those used by deep-sea explorers for obtaining marine specimens. With the net you get more specimens in proportion to the amount of water you collect.

To the end of a 3-foot handle attach a loop of heavy wire, about 9 inches in diameter. Heavy galvanized wire such as that used for fences is best. To this wire fasten a cone-shaped muslin net whose length is about 20 inches. At the small end of the net make an opening large enough to slip over the neck of a wide-mouthed

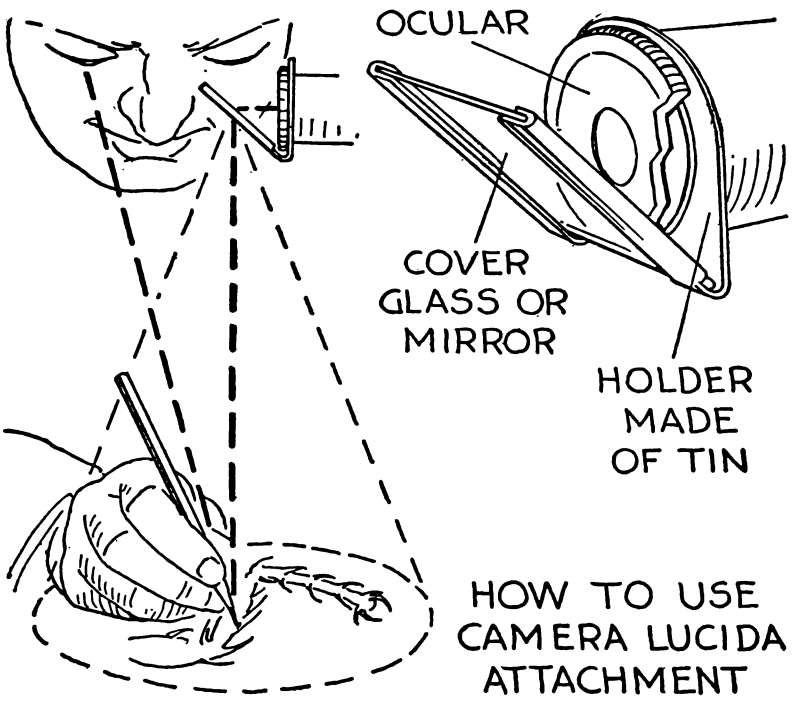
bottle of about 4 ounces capacity, and hem the edges. When ready to use the net, fasten it to the bottle with heavy rubber bands. This arrangement permits the bottle to be removed when it is full. To use the net,



simply draw it through the water where you suspect your microscopic quarry to be. Water will pass through the cloth, but the tiny plants and animals, that make such excellent microscope specimens, will be washed into the bottle.

Simple Drawing Attachment

Drawing with the microscope is easy if you use a simple attachment that you can make from a thin, square cover glass and a piece of sheet metal. The



HOW TO USE CAMERA LUCIDA ATTACHMENT

exact form of the holder will depend on your microscope eyepiece. The idea is to construct a device that will hold the cover glass at an angle of 45 degrees to the surface of the eyepiece, and with the center of the

glass at the axis or center line of the lens. Generally, it is possible to cut the sheet metal so that it resembles a washer equipped with two arms. The opening in the washer should be of a size to slip over the eyepiece tube but not over the knurled lens mount. The arms are bent to form slots, into which the cover glass slides, and are then adjusted so that the angle between them and the washerlike part is 45 degrees.

To use the device, tilt the microscope so that its tube is horizontal, and place a sheet of white paper directly underneath the drawing attachment. Adjust the cover glass so that its upper and lower edges are horizontal and the upper edge is tilted to the right or left. By looking at the center of the glass, you can see the image formed by the microscope and reflected into your eye by the surface of the cover glass; and you can see the paper through the glass. The result is that you see the image projected against the lighted paper, where you can trace it with a pencil. This attachment also can be used to measure the power of lenses if the size of the object being magnified is known, and to measure the object size when the lens power is known. When doing this, the distance from the eye to the paper should be the same as the distance from the eye to the image formed by the microscope's optical system. With standard instruments, this is about 10 inches.

CHAPTER X

CREATING A MICROSCOPIC SIDE SHOW

RIGHT this way, Ladies and Gentlemen. Step inside and see the most marvelous, most stupendous, most entertaining collection of natural wonders ever assembled! See the animal that has a thousand eyes, and the plant that eats flies! See the mummified dragon, captured after a long and thrilling chase in a fish bowl! See the priceless jewels of fantastic design, dredged from the depths of a stagnant pond! Everything guaranteed to be genuine: no fakes."

Thus might a side show barker ballyhoo his attractions if he were trying to get people to look at some of the preserved wonders of the microscopic world. A highly interesting show it is that he, or you or anyone else, could assemble, for the oddities of Microland outnumber and outclass those of the normally visible world.

No phase of microscopy is more fascinating than the making of permanent slides upon which are preserved specimens whose value is too great for only temporary study. Your side show of tiny wonders, a slide library, is concrete evidence of your tours through Microland. It is better than any photographic album in which are preserved scenes from some prosaic fishing expedition, or visit to Aunt Minnie's, because it is real, and because every slide in it recalls a thrilling little adventure

from which you emerged triumphantly bearing a tiny treasure.

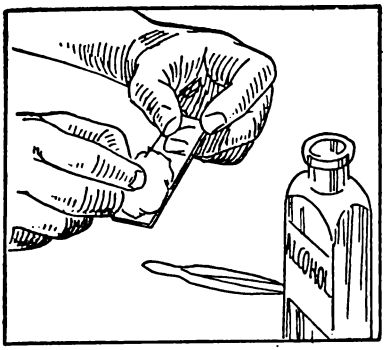
By all means start building up a slide library.

Before you tackle the making of permanent slides, however, you ought to become familiar with the chief methods of preparing and observing specimens that later are thrown away.

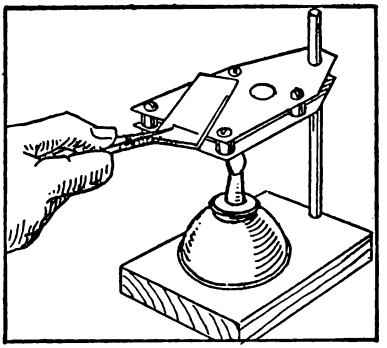
As you already know, the standard microscope slide used in this country is a piece of clear glass measuring 1 x 3 inches and having its edges ground and polished so that they do not scratch your hands or the microscope stage. With this slide is used a cover glass—a round, square, or oblong piece of very thin, flawless glass. The slide supports the object: the cover glass presses it against the slide, keeping it more or less in one place and making conditions better from an optical standpoint. Generally, square cover glasses are better for temporary mounts, and round ones for permanent slides.

When you get a dozen blank slides and a like number of cover glasses from a drug store or microscope supply dealer, you probably will find that they need cleaning. Simply wash them with soap and water, rinse, and dry on an old piece of linen. When cleaning the cover glass, hold it gently by the edges, between the thumb and first finger. Some microscopists recommend that both the slide and cover glass, when they are to be used for permanent mounting, be passed a few times through an alcohol or gas flame, to remove all traces of grease. Be careful not to warp the cover glass by holding it in the flame too long.

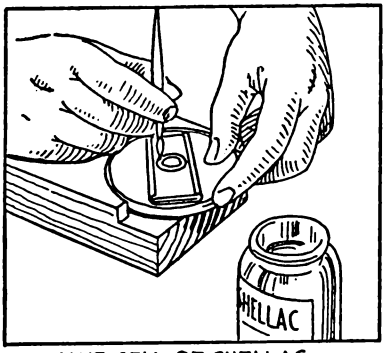
For temporary inspection of objects, you can use either a dry mount or one in which a fluid surrounds



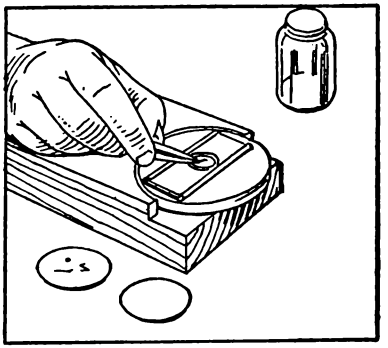
CLEAN SLIDE



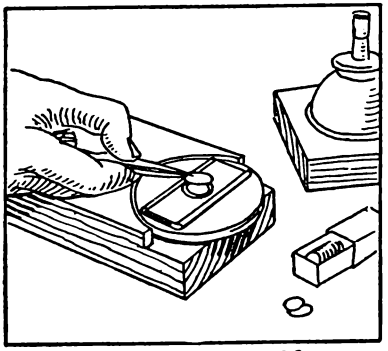
DRY WITH HEAT



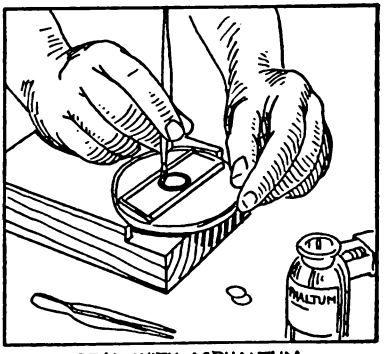
MAKE CELL OF SHELLAC



PLACE SPECIMEN



PUT ON COVER GLASS



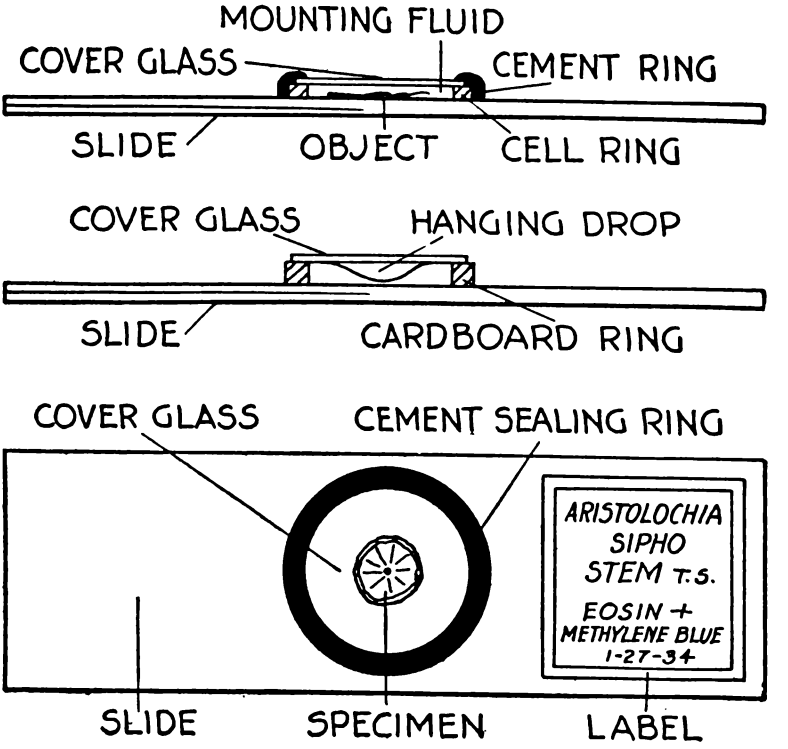
SEAL WITH ASPHALTUM

the object. Insect wing scales, bits of sea shell, salt crystals, textile fibers, metal specimens, woven cloth, and a host of similar objects can be observed dry, merely by placing them on the slide and perhaps dropping a cover glass over them.

You will discover, however, that many things look better when immersed in water, glycerin, or liquid petrolatum. Delicate hairs from plants, small insects and the parts from larger ones, algae, molds, bits of cuticle stripped from a plant leaf, the thousands of tiny animals that can be found in stagnant water—all these and more can be viewed while surrounded by a drop of water that has been pressed flat by the cover glass. Ordinary glycerin can be used, often with results superior to those obtained with water, for mounting plant specimens. Liquid petrolatum, the heavier grade, is used by some workers in much the same manner as water or glycerin, for specimens containing no water.

Sometimes, when you want to observe the commotion that is going on in a drop of stagnant water, or to look at some large-sized bacteria, you can use a hanging-drop arrangement. Make a circular or square ring of cardboard, glass, or anything else that is convenient. It should be somewhat larger all around than the cover glass. Lay the ring in the center of the slide, place the drop of specimen material in the center of the cover glass, invert it, and drop it carefully on top of the ring so that the water hangs down in the little well. Now you can look at the flattened part of the drop, having a much larger area over which to roam in search of wonders, instead of having to be satisfied with peering only at the center of the drop. If you use cardboard for the ring, moisten it to prevent evaporation. By

occasionally adding water to the cardboard ring, you can keep the drop hanging from the glass for a week or two, and observe the fascinating changes that are going on within it.



Unfortunately, everything that you will want to put under your lens cannot be viewed with satisfaction in its natural state. It is too large or thick, the parts you want to see are concealed inside, or there is not enough differentiation between parts of its structure to make

them distinct. So you have to cut it up into thin pieces, and perhaps "fix," clear, and stain the sections. Then you can mount it for temporary inspection, or make permanent slides.

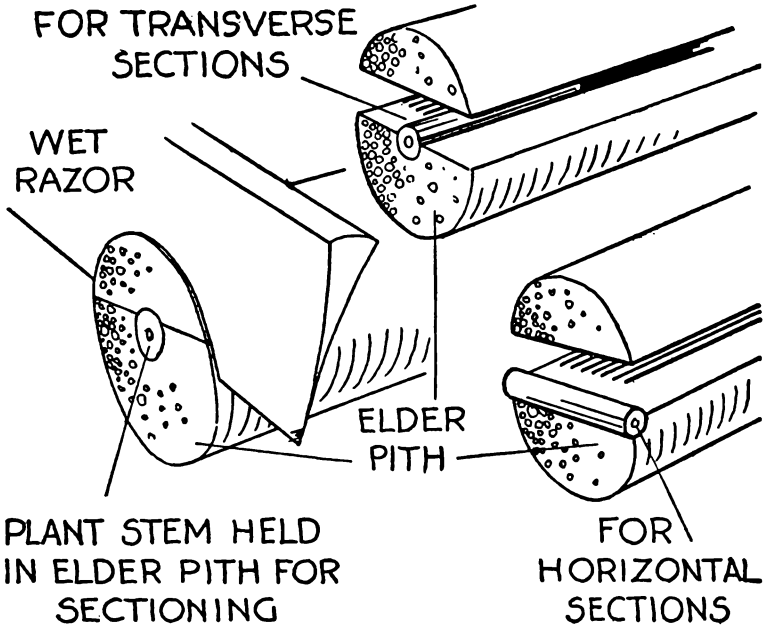
With a little practice, you can become skillful in cutting sections of plant and animal material, with nothing more than a razor, either the straight-edged kind, or a safety-razor blade in a holder. You can hold some things in your fingers while you slice them. Others will require special mounting.

You will find plant specimens easier for practice in cutting than most animal objects. Young buds, stems, roots, and a host of other things in the plant kingdom will surprise you with their beauty, if you slice them up.

A great many plant sections can be cut while fresh, without special preparation other than wetting the razor blade to make it glide easily. Other plant material will crush into a hopeless mass if you attempt to cut it as you find it. It must be "fixed"; that is, the living cells must be killed quickly and then preserved in their original form. There are various ways of fixing plant specimens. One is to drop them into absolute alcohol, leaving them for several minutes or a few hours. Alcohol is suitable for small pieces. Another fixing preparation that is preferred by some botanists for larger objects is a solution of chromic and acetic acids, which you can obtain cheaply from a druggist. The formula for a medium strength bath is:

1 per cent chromic acid.....	7 ounces
Glacial acetic acid.....	24 drops
Distilled water.....	3 ounces

The specimen is left in this solution for about 12 hours. For delicate specimens, such as algae and molds, the solution can be diluted with 5 parts water containing 6 ounces of 1 per cent chromic acid.



Animal tissue can be fixed by placing it in a 10 per cent formalin solution for 12 hours.

Years ago there was introduced a method of using dry elder pith for holding delicate plant parts while they are being sliced by hand or with a hand microtome. This pith can be purchased cheaply from scientific supply companies, or you can gather your own from the insides of large elderberry plant stems, and

dry it. It is easy to slice pith into thin sections with a razor, particularly if both pith and razor have been wet with water. If a plant stem or flower bud happens to be embedded in the pith, it is therefore sliced neatly.

To get the root or other plant part in the pith for making transverse sections split the pith cylinder lengthwise slightly to one side of the center. In the larger piece, make a depression just large enough to hold the specimen firmly. Replace the smaller piece of pith, and bind the two together with thread or a rubber band. Wet the pith and slice. For long, slender specimens that are to be sliced lengthwise cut a groove across the end of the pith rod and press the specimen into it. Then slice thin disks off the rod, as previously described, where the specimen is embedded.

A way of holding delicate parts of plants, insects, and the like by surrounding them with a wax made by melting together paraffin and tallow was suggested years ago by Koch. It is simpler and quicker than the somewhat elaborate method employed in laboratories for embedding specimens in paraffin.

Equal parts of paraffin and tallow are mixed together. This produces a material that melts at low temperatures, so that delicate specimens can be handled without injury from heat. Just before being plunged into the melted paraffin-tallow, the specimen, a plant root for instance, is placed in alcohol for a minute or two and then removed and kept in the air until the alcohol has evaporated. This removes the surface moisture and prevents formation of troublesome bubbles. The specimen is then placed in the wax, which is allowed to harden. It is cut into sections with a razor. The sections are given brief treatments in

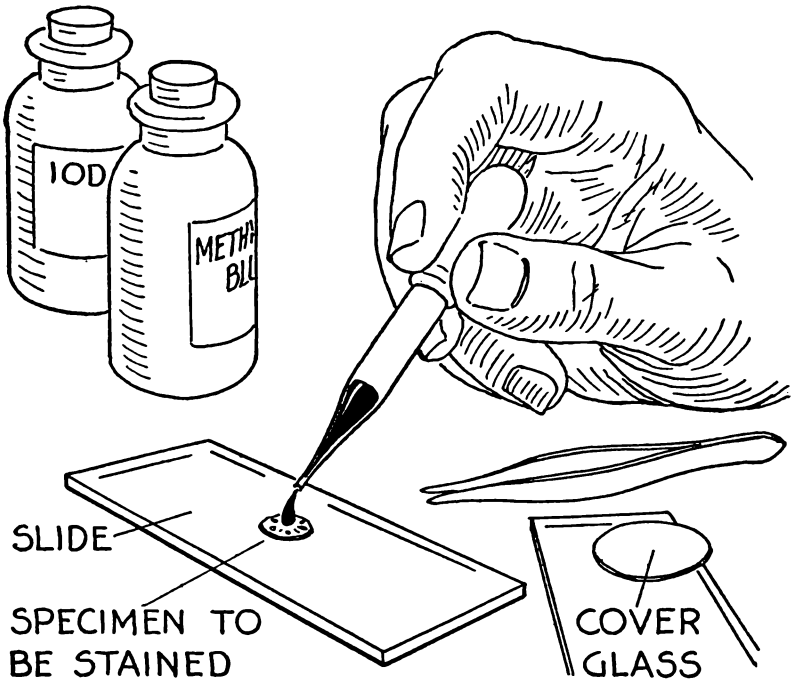
xylol followed by alcohol, and then are ready for further handling like any other fresh material. This method should appeal especially to the amateur.

For the standard method of embedding plant and animal tissues and other parts in paraffin after every trace of water has been removed, you are referred to any of the various books dealing with this somewhat involved process. Botanical laboratory handbooks, such as that by Bergen and Davis, explain how to embed and mount plant specimens by the paraffin method. Similar books dealing with zoology can be consulted for information on paraffin embedding of animal materials. "Practical Bacteriology, Blood Work, and Animal Parasitology," by Dr. E. R. Stitt, describes briefly the fixing, dehydrating, clearing, and embedding of animal tissue.

A quick method of hardening plant or animal materials for cutting into thin sections without crushing delicate cell structures is to freeze them. Laboratories use compressed carbon dioxide that, by escaping through an expansion chamber, quickly freezes anything that is placed on top of the chamber. The amateur will find the ice-cube compartment of the electric or gas refrigerator a convenient place to experiment with freezing specimens. Simply place the piece of mushroom stem or beef muscle on a watch glass and set it in the freezing chamber. The specimen should, of course, contain water. Dry specimens are soaked in water first. When the object has frozen, slice it in the usual manner. It may require some experimenting to determine the proper degree of hardness. If you have no automatic refrigerator, you can place the specimen in a container, such as a small tumbler or beaker,

which is surrounded by a mixture of salt and cracked ice or snow. Leave until frozen.

Did you ever wonder what the inside of starch grains, microscopic leaves, spores, pollen grains, insect



eggs, and tiny seeds look like? With your microscope, you can find out.

First it is necessary to slice these tiny objects into thin sections, or at least split them in two, a process not so difficult as it sounds. Simply mix some concentrated glycerin with gum arabic to form a doughlike mass. Into this mix the spores or starch grains and

stick the dough on the end of a cork to harden, after which it can be cut into pieces of random thickness and shape with a razor. Drop the pieces into a little water to dissolve the dough, and then pick up the specimen particles with a dropper.

Before mounting a microscopic specimen on a slide, you may want to stain it. The stain can be applied after the material has been placed on the slide, by simply adding a drop or two of the staining solution, or the object can be immersed in the stain long enough to soak up the color. Some materials have to be dehydrated before they will stain well. There are scores of stains available, iodine, eosin, haematoxylin, and methylene blue being suggested for use at first.

When you mount a specimen permanently on a slide, you become for the moment a kind of undertaker, embalming your microscopic corpse in a fluid that will prevent decay.

There are some things that you can preserve without embalming fluid by using a dry mount. Insect wing scales, bits of shells, beetle-wing covers, and cloth fibers are among these. Usually the specimen is of considerable thickness as microscopic objects go, so you will have to construct a cell by spinning one of shellac, or by cutting washers of cardboard or celluloid and cementing them on the slide with balsam or shellac. Into the cell place the dried wing scales or other objects. It may be advisable to arrange the specimen so that it cannot move about in its enclosure. You can do this by covering the bottom of the cell with a thin layer of balsam and then carefully pressing the specimen down against it. Finally, apply the cover glass and cement its edges to the washer or shellac

ring by applying asphalt varnish, gold size, or shellac. You can purchase the varnish or size already mixed, from a microscope supply dealer; and the shellac you can obtain at any paint store.

The most widely used embalming fluid is Canada balsam. A filtered type is sold specially for microscope slide making, frequently in a collapsible tube like toothpaste. Balsam is soluble in xylol, so that, if it becomes too thick, it can be thinned by adding a small amount of the solvent. Likewise, xylol can be used to clean balsam from slides, cover glasses, instruments, and your fingers.

To mount an object in balsam is the work of a minute. Place on the slide a drop of balsam, more if necessary when you are using a cell. The specimen must be thoroughly dry. This can be accomplished by warming in air or immersion in absolute alcohol, followed by evaporation of the alcohol in air. Just before immersing the specimen in the balsam, place it in xylol for a short time. Then transfer it to the slide, arranging it in the balsam with a dissecting needle. Drop the cover glass on the balsam. Sometimes the weight of the glass will spread the balsam out evenly; at other times you will have to manipulate it gently with a needle. You can place the slide in a clamping device to hold the cover glass in place, if it refuses to stay in position of its own accord. Do not worry about small air bubbles that may be imprisoned: they will work out as the balsam hardens.

The embalming job is now complete except for possible application of a ring of asphalt varnish around the edges of the cover glass. In the balsam, the microscopic treasure will keep for years. Finally, clean the

slide and cover glass, label and file in a slide box such as has been described previously.

It happens that balsam is not a universal embalming fluid. Specimens containing some water, such as parts of plants, cannot be preserved successfully in it. In such cases, glycerin jelly is preferable. You can make, for a few cents, enough jelly to embalm hundreds of objects, as follows:

Pour 1½ ounces of distilled water over ¼ ounce of sheet gelatin and let stand for two hours, until the gelatin softens. Add 1¾ ounces of concentrated glycerin and 30 grains of phenol (carbolic acid crystals). Heat this mixture gently in an enameled pan over a low flame for 10 or 15 minutes, stirring constantly with a glass rod. While still hot, filter through a pad of moistened cotton placed in a funnel. Pour enough of the jelly into a test tube to fill it about half, and store the remainder in a bottle. Keep both of them corked to eliminate dirt. The jelly hardens when it cools.

Transfer the specimen to be mounted from water to a mixture composed of about 1 part glycerin to 1 part water. Let it remain there for a while, then place in pure glycerin.

Melt the jelly in the test tube by immersing in warm water or holding over a flame, and with a glass rod transfer a drop to the glass slide, which also must be warm. Transfer the specimen from the glycerin to the jelly, arrange it with a needle, and add the warm cover glass. You will learn to do this very quickly, so that the jelly does not harden. If it does, it can be melted by holding the slide high over a flame. Be careful not to imprison air bubbles. If you do, you prob-

ably can force them out by gentle heating. After the glycerin jelly hardens, you can spin a ring around the cover glass with asphalt varnish or shellac.

Stitt recommends the use of liquid petrolatum for both temporary and permanent mounting of certain objects. You can get petrolatum at a drug store, very cheaply. Ask for the heavy grade, in a dropper bottle. It is as easy to handle as water, requiring no heating or thinning to make it behave. Furthermore, it has better optical properties than most other embalming fluids. A tiny insect or honey bee's wing mounted in it is remarkably clear and distinct.

Other objects that you can mount in it include bacteria, spore cases of molds, and various other dried specimens. For permanent mounts, have the specimen free of water, and use just enough petrolatum to fill the space beneath the cover glass. Then, after wiping away any excess with a piece of blotting paper or cloth, tack the cover glass in place by touching it at several points around its edge with a brush bearing a little shellac. When this has hardened, you can spin a shellac ring around the edges, or apply gold size.

You may decide that the process of preparing a specimen and mounting it on a slide is too involved to prove interesting, particularly if you look up the routine dehydrating and embedding in paraffin. On the contrary, slide-making, perhaps because of the very manipulations that make it seem involved, is one of the most fascinating phases of amateur microscopy. That is proved by the fact that many amateurs lose little time in starting a collection of slides, and develop the habit of making a permanent mount of every important treasure they obtain during their tours through

Microland. If your hobby eventually leads to a position in a large research laboratory, you will find that slide-making is an absolute necessity. The government, for instance, employs men whose duties consist essentially of nothing else but slide-making. Large milling companies and other industrial concerns sometimes make thousands of slides during the process of solving a single research problem.

But the most attractive part of slide-making is that it is a lot of fun!

How to Make a Projecting Microscope

If you would like to view your interesting microscopic specimens on a larger scale, you can do so by building the novel projector shown in the drawings. With it, you can enlarge the strange world of the microscope to motion-picture proportions.

Made almost entirely of odds and ends, the projector is a simple optical system consisting of a home-made carbon arc, two inexpensive condenser lenses, and an 8- or 16-millimeter objective lens mounted on an easily constructed base. The condenser lenses can be any units—hand magnifying glasses, for instance—having a focus of not more than 6 inches while the objective lens can be borrowed from your microscope.

Your first task will be to make the base. This is a rectangular piece of wood having two supports mounted on its upper face. Running through these supports is the lens rail, which serves as a mounting for the lenses. This can be a square stick of wood measuring approximately 1¼ inches on a side or a length of angle iron of similar proportions.

At the rear of the projector is the light source com-

A HOMEMADE
PROJECTING
MICROSCOPE

posed of two carbons so arranged that their tips can be moved closer together or farther apart. The mountings for the carbons can be improvised from discarded knife-blade switches or made by bending stiff copper wire into springlike coils.

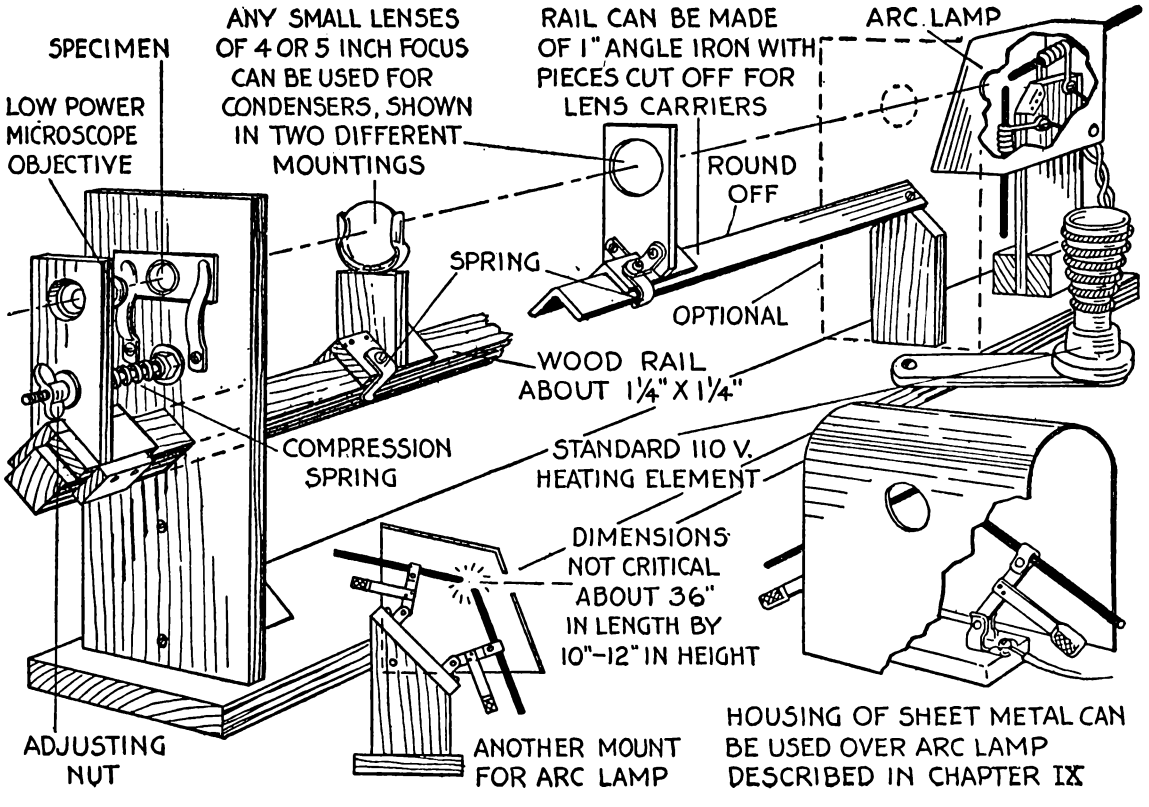
As indicated, the electrical circuit consists of a regular heating element connected in series with the arc and the house lighting circuit. Incidentally, a brighter light will be obtained if about one-third of the wire is removed from the heating element.

If you have alternating current, both carbons should be of the 8-millimeter variety. With direct current, a 6-millimeter carbon should be placed in the vertical position and an 8-millimeter carbon in the horizontal position. If a wooden mounting block has been used to support the carbons, protect it from the heat by sheathing it in sheet metal or asbestos.

To shield the light, you can make a suitable cover for the arc from sheet metal. This should be arranged so that it can be removed easily to allow adjustments and replacements to be made. Also, if you desire, a circle of red glass can be mounted in one side of the cover to serve as an inspection window.

Since in focusing, the condenser lenses will be adjusted, they must be held in some convenient mounting that will allow them to be moved along the lens rail. Several suggestions for these mounts are given in the drawings. The clips, used to hold the mounts in place on the rail, can be made from wood or spring metal.

A similar mount also is used for the objective lens. However, an accurate and steady means of moving the objective along the rail must be supplied. The simplest arrangement that will give this adjustment is an ordi-


SPECIMEN
LOW POWER MICROSCOPE OBJECTIVE
ANY SMALL LENSES OF 4 OR 5 INCH FOCUS CAN BE USED FOR CONDENSERS, SHOWN IN TWO DIFFERENT MOUNTINGS
RAIL CAN BE MADE OF 1" ANGLE IRON WITH PIECES CUT OFF FOR LENS CARRIERS
ARC LAMP
ROUND OFF
SPRING
OPTIONAL
WOOD RAIL ABOUT 1¼" X 1¼"
COMPRESSION SPRING
STANDARD 110 V. HEATING ELEMENT
DIMENSIONS NOT CRITICAL ABOUT 36" IN LENGTH BY 10"–12" IN HEIGHT
ADJUSTING NUT
ANOTHER MOUNT FOR ARC LAMP
HOUSING OF SHEET METAL CAN BE USED OVER ARC LAMP DESCRIBED IN CHAPTER IX

nary wing nut threaded on the projecting end of a long bolt passed through the front support and the lens holder. A lock nut, screwed tightly against the front support, will hold the bolt in place, and a coil spring slipped over the shank of the bolt between the two supports will make the adjustment work in both directions.

The front vertical member should be supplied with an aperture hole and two spring clips for holding the specimen slide in place. The aperture hole should be large enough to allow the light from the arc and lens system to strike the slide while the clips can be taken from the observation stage of your microscope.

With the arc circuit plugged into a convenient socket, you are ready to make the final adjustments on your projector. First of all, make sure that the light source and the center of the objective lens line up accurately with the aperture hole and the centers of the condenser lenses. This is important as any variation will upset the optical system.

When you have adjusted the arc to give the best possible light, darken the room and adjust the condenser lenses to form a brilliant circle of light on the aperture hole. This is done by removing the condenser lens nearest the objective and moving the rear lens back and forth until the position is found that gives a sharp spot of light. Then, leaving it in that position, replace the front lens and adjust it until the spot again becomes sharply defined.

Finally, to view a slide, place it under the clips on the front support and adjust the objective lens until a clear image is formed on the screen. Incidentally, the screen, which may be anything from a white wall to a

large square of white cardboard or sheeting, should be placed about five or six feet from the projector.

Although the ordinary specimens in your library of prepared slides will form excellent subjects for use in your projector, the tiny creatures they contain are dead. By making up special aquarium slides, you can study living subjects just as you would with your microscope.

For example, to view the weird creatures that inhabit a drop of water place a drop of the water in the depression of a well slide and slip a cover glass over the top. Capillary attraction will hold it in place without the aid of cement. To keep the inmates of your water slide alive overnight, slip the cover glass slightly to one side and place a drop of water, taken from the same source as the original, over the opening.

If you find that a great deal of heat from the arc reaches the aperture hole, you can protect the specimens in your aquarium slides by building a simple cooling cell and placing it between the two condenser lenses. The cell, which contains water to cool the light beam, consists merely of two pieces of high-grade window glass, a short length of rubber tubing, and two homemade wooden clamps. The rubber tubing, bent U-shape and clamped between the rectangles of glass, forms a watertight well. Mount this cooling cell on the lens rail by using a clip or clamp similar to those supporting the lenses.

CHAPTER XI

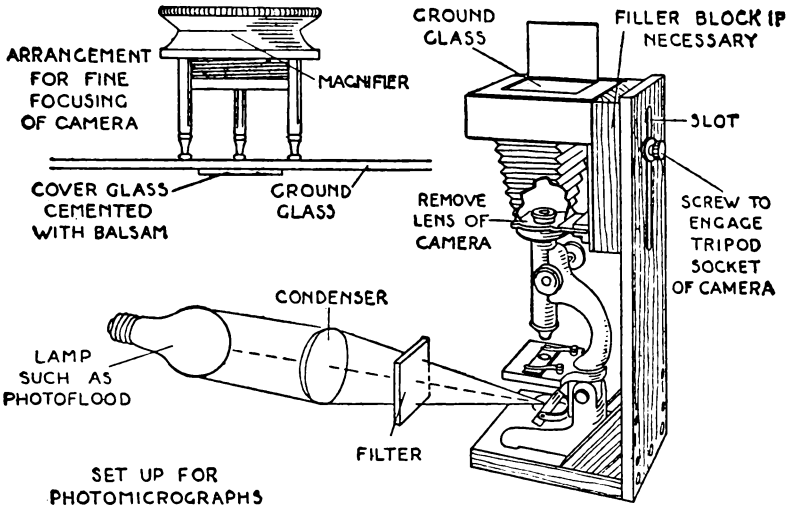
RECORDING THE WONDERS YOU SEE

JUST as you feel the desire to make a snapshot of a beautiful building or buy a souvenir card bearing its picture, you will want to make permanent records of some of the wonders you encounter in Microland. Beautiful patterns traced by crystals of some chemical evaporated on a slide, delicately-figured Diatoms, cross sections of plant stems—all these things and scores of others make fascinating subjects for your camera when you employ it in conjunction with your microscope. Aside from the pure pleasure you derive from making them, photomicrographs may serve a useful purpose. They may be employed in connection with school or other work. Perhaps you can sell some of them for profit. Maybe you will develop, as some amateurs have, into an accomplished photomicrographer, with a world-wide reputation. But the chances are that you will find reward enough in the sheer fun of assembling an album of Microland pictures.

Any microscope can be used with a camera to make photomicrographs, provided a little care is exercised. The expert who uses a photographic layout that cost a thousand dollars probably would shudder at such a statement; but nevertheless surprising results have been obtained with equipment that looked like something dragged out of the ash can. Some of the best

photomicrographs ever exhibited were made with old-fashioned lenses, and with an oil lamp as a light source!

The best camera to use with a microscope is one that has a ground-glass focusing screen. However, this is not absolutely necessary. Any camera of the focus-



ing type can be employed without removing its lens, if the focusing scale is set at "infinity," or at "100 feet" if there is no infinity mark.

Arrange the camera and microscope so that the camera lens is directly in line with the microscope eyepiece and tube. Then remove the camera for the time being, place on the microscope stage the slide bearing the object to be photographed, adjust the mirror until the field is evenly and brightly illuminated, and the focus as sharp as possible. Then, with-

out disturbing the position of the microscope or the focusing knobs, return the camera to its position in line with the eyepiece. Wrap a black, dustless cloth around the microscope tube and press it up against the camera, to make the connection light-tight. With the film in place, open the camera shutter and make the exposure; or, better still, switch the light on and off without touching the camera or microscope. You will have to determine the exposure time by trial. The magnification of the resulting image generally is less than that observed visually through the microscope, particularly with short-focus camera lenses.

If the camera has a ground-glass focusing screen, or can be equipped with one in the plane of the sensitive film, remove the camera lens and place the microscope so that its eyepiece enters the front of the shutter or lens-board, or presses against it. Add the light-proof cloth, and focus the microscope image directly on the ground glass, as you would in taking any other picture.

You will experience fewer disappointments and produce better results if you learn to make passable pictures of houses and landscapes and people with an ordinary camera before you tackle photomicrography. Then, since the making of photomicrographs is a fascinating hobby in itself, and a lot more fun than photographing ordinary things, you will be repaid many times over if you devote a little time and effort to assembling a really effective photomicrographic outfit.

If you do not already have a camera that can be equipped with a ground glass, you can pick up one for a dollar or two at a second-hand shop or from a photographic dealer who handles used cameras. If it has a fairly decent bellows, a ground glass or a place to put

one, a plate or cut-film holder, and perhaps even a shutter, it will serve nicely. Don't worry if there is no lens, because you will use only the microscope lenses anyway. Size of the film used does not matter much, although 4 x 5 inches is convenient and economical.

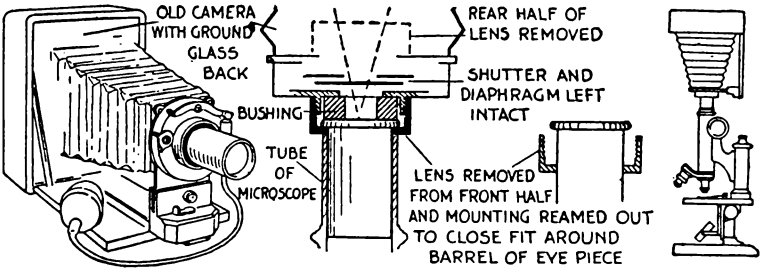
After wiping off the dust and patching a few holes in the bellows, measure the size of the camera when unfolded, and the length of the microscope from base to eyepiece, and construct an L-shaped wooden stand similar to that illustrated. In the longer or upright piece, cut a slot through which you can pass a bolt to engage the tripod socket threads. The slot permits the height of the camera to be adjusted, for regulating the image size. When the ground glass is near the microscope eyepiece, the image will be small; when farther away, it will be larger.

You need not use a conventional camera at all, if you find difficulty in obtaining one. Simply build a light-tight box of the same general shape as a camera, make a hole in one end for the microscope eyepiece and arrange a ground glass focusing screen and a film or plate-holding device at the other. Make sure, with this camera as with any other, that the ground surface of the glass and the sensitive film or plate surface are in exact register. Otherwise you will get blurred pictures.

On the ground surface of the focusing screen draw, with a fine-pointed pen dipped in India ink, two lines that cross in the center. Place a drop of Canada balsam on the ground side at this point and press over it a clean cover glass. This produces a clear spot through which light rays from the microscope pass. By using a magnifier, such as a 7½-power tripod type

costing 75 cents, you can enlarge the microscope image and focus more sharply than you could with the ground glass alone. The magnifier must be adjusted so that the cross lines are in sharp focus.

For connecting the microscope to the camera, you will find a simple sleeve made of several layers of black cloth effective. The sleeve is slightly larger inside than the microscope tube, and is fastened over a hole



SELF-SUPPORTING CAMERA FOR PHOTOMICROGRAPHS

in a board at the front end of the camera. To attach the microscope, slip the sleeve over the eyepiece end and bind the cloth snugly with a string or rubber band.

Almost any kind of light can be used for illuminating the object. A frosted-bulb incandescent lamp will serve. If a great amount of light is wanted, you can use a 35-cent photoflood bulb, which gives about 750 watts effective illumination and burns for at least two hours. A common oil lamp, placed so that the flat side of the flame can be reflected by the microscope mirror, is excellent for many kinds of specimens. Some experienced microscope workers prefer sunlight to anything else, but admit that it is unreliable because it varies.

Still, this is no drawback when you have to guess at the exposure anyway, as is the case with most pictures. Among the more intense sources of artificial light are the electric arc lamp and the 108-watt microscope lamp having a ribbon filament.

But whatever the light source, always adjust the mirror and other apparatus until the focusing screen is evenly flooded with light. You will find that a very slight movement of the mirror or beam of light will cause trouble. It is for this reason that photomicrographic equipment generally is set up in basements where there is little vibration, is used when vibration from heavy traffic and other sources is lacking, and is equipped with shock-absorbing springs or pads of felt or rubber. You can use several thicknesses of felt beneath the legs of the table, or under the camera stand, to advantage.

You will discover, before you progress very far, that you can photograph opaque objects like pieces of rock, thick insects, and crystals by illuminating them from above. A little experimenting will reveal the best position for lights. A good rule to follow is that the illuminating of an opaque microscope object is essentially the same as lighting a person's face for a portrait. In industry, the making of photomicrographs of surface details is of great importance. The crystalline structure of metals and metal alloys is photographed in this way, after being polished and etched with acids or other reagents to bring out the grain. The development of a new paint or lacquer for wood or metal finishing generally involves the making of hundreds of photomicrographs of test coats.

By learning how to employ light filters, you can im-

prove the performance of your microscope when you use it to make photographs. Even the best microscopes are not entirely free from defects resulting from the lack of complete color correction. The lens maker is not to blame, for science has not yet learned how to make lenses that will focus all the colors of light at one point. Also, most microscopes are made to be used with the human eye, which sees differently from the camera film.

You can employ pieces of colored cellophane or other material to control the color of light entering the microscope and camera. Place the filter between the mirror and light source. The best type of color screen to use is one designed specially for photomicrography. You can buy such filters in sheet-gelatin form through any photographic supply house. The cost is 10 cents per square inch for pieces measuring 4 square inches or more. Thus a 2- x 2-inch filter, which is plenty large enough, costs 40 cents. Mount the gelatin between two pieces of clean glass bound at the edges with lantern-slide tape. Do not touch the gelatin with your fingers or any other moist article.

A green filter will make most microscopes perform better for black-and-white and other objects where color correction is not important. If you want to photograph a red-stained specimen for maximum contrast, use a blue filter; if for maximum detail, use a red or yellow one. Likewise, a red filter gives greatest contrast with a blue specimen, and a blue filter greatest detail. The best guide is direct observation of the effect of a filter on the image projected against the ground-glass focusing screen.

Ordinary (orthochromatic) films or plates can be

used when blue or green filters are employed. When red light is used, the film must be sensitive to it, must be panchromatic, in other words. Because panchromatic films must be developed in total darkness or by a special green safelight, they are a little more difficult to use. However, the superior results they give are worth the added trouble. For the greatest contrast, you can use panchromatic process films or special photomicrographic plates such as the "M" type. Both panchromatic and regular films can be obtained for roll-film cameras, as well as for those using cut-film.

It is a good rule to use the developer and fixing bath recommended by the film or plate manufacturer. Sometimes it may be of advantage to use one of the special fine-grain formulas, so that the negative can be enlarged to a considerable degree. Thus, a photomicrograph whose magnification measured on the negative is 200 diameters will, if enlarged 10 diameters by projection printing, result in an image 2,000 times the size of the original!

Always keep a complete record of each exposure, and mark each negative with India ink, so that positive identification will be possible after you have forgotten the facts connected with its making. In this way, you soon will learn to make good negatives.

As for prints, produce the best ones you can, and mount them in an album or otherwise preserve them. Then when you are telling a friend about some amazing sight you saw through your microscope, and the friend thinks you are offering him applesauce, you can produce photomicrographs to support your statements. You will find, before you travel far in the wonderland your microscope throws open to you, that when you

cannot exhibit the original specimens, it is difficult or impossible to describe the wonders clearly to a person who is not himself a microscope hobbyist. With the aid of your album, you can make such tales of adventure more understandable and interesting.

If you have a photomicrographic camera rigged up, you can use it to make drawings by replacing the focusing screen with a piece of clear glass and laying over it a piece of thin, white paper. The microscope will project an image on the paper, as a magic lantern does, and you can trace the outlines with ease. In a similar way, a mirror or right-angled, totally reflecting prism can be arranged to reflect an image on a piece of paper placed on a table. The paper must be shielded from outside light; and a fairly intense light on the object generally is required.

By measuring the size of the projected image and dividing by the number of diameters the microscope magnifies, you can determine the actual size of the specimen. Of course, some error may be introduced because the distance from the microscope eyepiece to the drawing is not correct. For standard microscopes, the distance should be 10 inches. For amateur types, it can be made the same as the distance from the eyepiece to the slide, which will give results nearly enough accurate. The magnification produced by low-power lenses can be measured with exactness by focusing on a millimeter scale and then measuring the distance between two lines on the scale as reproduced in the image, the measurement of course being in millimeters. Thus, if the distance between two successive lines on the scale is 25 millimeters, the microscope is magnifying 25 diameters.

APPENDIX

A—Alcohols.
B—Notes on Construction of Cells for Thick Objects.
C—Irrigating Specimens Mounted in Water.
D—Metric-English Units.
E—Low-Power Photomicrography.
F—Putting Brakes on Active Protozoa.
G—Microscopic Stains: Some Formulas.
H—A Quick Method of Developing Negatives.

A—Alcohols: When the word alcohol appears in books and magazines, it generally refers to ethyl alcohol made by fermenting a sugar. Wood alcohol or methyl alcohol is an entirely different substance, and is of interest to the microscopist mainly as a preferred fuel for his alcohol lamp. When obtaining alcohol for use in fixing plant materials, dehydrating specimens, or performing some other operation, ask for grain alcohol or ethyl alcohol. Denatured alcohol, which probably can be used with success in most cases, is ethyl alcohol with a poisonous substance added to prevent its use as a beverage. Get, if possible, absolute alcohol, which is not denatured. The next best is 95 per cent alcohol. Absolute alcohol contains no water. One way of extracting water from diluted grades is to suspend gelatin in it. The gelatin absorbs water but not alcohol. It can be dried and used over again.

To make alcohols of lower percentages, dilute abso-

lute or 95 per cent with water. For preserving specimens such as insects and plant tissues indefinitely, mix 95 per cent alcohol with about half its weight of water.

B—NOTES ON CONSTRUCTION OF CELLS FOR THICK OBJECTS: Construction of cells for mounting thick specimens on glass slides has been considered elsewhere in this volume. However, a few additional notes may be of value:

Substances suitable for cutting washers for separating cover glasses from the slide include photographic film from which the gelatin has been removed. The so-called cut-film is thicker than that used in rolls. Both are coated on front and back with gelatin. To remove this, soak the film in hot water and scrape the softened coatings off. Another way is to soak the film in muriatic or hydrochloric acid, until the gelatin coatings dissolve completely. This can be done after the rings have been cut, necessitating less acid.

Other materials from which rings can be made include cellophane for very thin specimens (some difficulty might be experienced when using waterproof cellophane with some mounting materials); paper or cardboard soaked in shellac and dried; thin fiber such as that used in electrical work. Sometimes it might be desirable to use colored rings, to dress up the slide a bit. Another way of improving the appearance, and one that requires little fuss or time, is to cut rings, somewhat larger than the cover glass, from gummed paper such as black or dark blue passe partout. When the balsam has dried thoroughly around the cover glass, scrape off the excess with a razor blade and wipe with a cloth moistened in xylol. Then moisten the gummed ring sufficiently to soften the paper, place over the

cover glass so that it protrudes equally all around, and iron the edges down with a crochet hook or other blunt instrument.

Gold size and asphalt varnish are widely used for sealing cover glasses and at the same time improving the appearance of the slide. Gold-size cement, as described by Beale, is prepared by boiling together for three hours ⅓ part umber, 1 part vermillion, and 25 parts pure linseed oil. Pour off the clear liquid and add slowly equal parts of yellow ochre and white lead until the proper consistency is obtained. Boil a while longer, and then bottle. Perhaps you will prefer to buy gold size already prepared, for about 40 cents an ounce.

Asphalt varnish, sometimes called Brunswick Black, is made by dissolving asphalt in equal parts of turpentine and linseed oil. You may have difficulty in making a preparation that will harden properly, due, perhaps, to a poor grade of oil. This popular cement is sold ready-mixed.

Quick-drying lacquer or four-hour varnish enamel can be used in ringing slides. Either material produces a neat job. Perhaps the four-hour varnish enamel is to be preferred to lacquer, as some lacquer solvents will dissolve almost anything.

C—Irrigating Specimens Mounted in Water: When you are examining specimens in water under a cover glass, it sometimes becomes desirable to introduce fresh water in order to wash out stain or impurities. This can be done easily by inclining the slide and, with a dropper, adding the fresh water to the upper edge of the cover glass. Excess water will drain off at the bottom.

D—METRIC-ENGLISH UNITS: Length:

1 inch = 2.54 centimeters or 25.4 millimeters.
10 millimeters = 1 centimeter = 0.3937 inch.

Measurements of the thickness of very thin microscopic specimens, size of details of specimens, and wave lengths of light are made in thousandths of a millimeter, or microns. One micron equals 0.000039 inch. The symbol commonly employed for the micron is the Greek letter, μ (mu). Thus, when a microtome is set to cut sections 7 microns thick, it slices them $\frac{7}{1000}$ millimeter, or 0.000273 inch thick. Wave-length of light is measured in microns.

Volume:

1 cubic centimeter (cc.), also called milliliter (ml.) = 0.03381 U. S. Liquid ounces.
1 U. S. liquid ounce = 29.574 cubic centimeters.

Weight:

1 grain (about $\frac{1}{437}$ ounce) = 0.06480 grams.
1 gram = 15.4324 grains or about $\frac{1}{28}$ ounce.

E—LOW-POWER PHOTOMICROGRAPHY WITH CAMERA LENSES: By increasing the bellows draw of a camera to several times the normal focal length of the lens, photographs of small objects can be taken at magnifications up to 40 or 50 diameters. The shorter the rated focal length of the lens, the less cumbersome the arrangement will be. Motion-picture and miniature camera lenses of 1- or 2-inch focus are excellent. The construction of a long tube, with the lens mounted at one end and the plate or film holder at the other, is not

difficult or expensive. Ordinary 7-inch stove pipe, painted on the inside with a mixture of drop black in thinned shellac, or rendered non-reflecting by some other means, serves excellently. It is absolutely necessary that there be no internal reflections. Of course, the object being photographed must be placed very close to the lens, and properly illuminated, either as a transparent or an opaque specimen. The lens generally must be stopped down to gain sufficient depth of field. Remarkable photographs of small insects and other interesting objects have been made with such an arrangement.

F—Putting Brakes on Active Protozoa: Active protozoa and other small animals that dash rapidly about in the water under a cover glass are difficult to study in their natural state unless some means of throttling their travels is employed. Some microscopists use a network of frayed cotton or silk fibers, placing it on the slide, adding the water containing specimens, and then putting the cover glass in place. Of course, the fibers interfere somewhat with vision; but usually some of the life forms can be trapped in a little lake whose fibrous shores will keep them in the microscope field.

G—Microscopic Stains: A few standard staining formulas have been given elsewhere in this book. Here are a few more that you will find useful as your staining adventures expand. Use distilled water in mixing:

Iron-Alum Haematoxylin. Suggested for algae, fungi, Protozoa, etc.

Make two solutions:

(A)—A 2 per cent solution of iron alum (ammonium sulphate of iron) in water.

(B)—A ½ per cent haematoxylin solution. Dissolve in hot water.

To stain a specimen, place first in A for 3 to 6 hours, wash in water a few minutes, and then place in B for several hours, or a half-day. Return to A to extract the black deposit. When this has been done to the desired degree, place in clear water to remove the iron alum. Then mount in the usual way.

Safranin:

Simply dissolve the safranin in alcohol or water. Some workers prefer to use a saturated solution in 50 per cent alcohol.

Methyl Green: (See Acid Fuchsin)

Make a saturated solution in distilled water or in 1 per cent acetic acid.

Acid Fuchsin. Brilliant and rapid:

Make a 1 per cent solution in water or alcohol.

Acid fuchsin and methyl green are used together in botanical preparations. Stain with the methyl green for several hours, wash in water, and then stain for a few minutes in acid fuchsin.

Delafield's Haematoxylin:

This is one of the most frequently used haematoxylin formulas, and is employed frequently in conjunction with other stains such as safranin and eosin. Its preparation extends over considerable time, so that it is best to purchase it from dealers whenever possible.

H—A Quick Method of Developing Photographic Negatives: When making photomicrographs, each exposure is largely a matter of guesswork, so that it is advisable to develop each negative as made, before changing the set-up for the next picture. The following method of divided development will

enable a film or plate to be developed in one minute, and the result of the exposure to be known positively within two or three minutes, or as soon as the hypo has had time to work for a minute or two:

Solution A:

Water	8 ounces
Elon	30 grains
Hydroquinone	90 grains
Sodium Sulphite	¾ ounce
Potassium bromide, 10 per cent solution	40 drops

Solution B, for average contrast:

Water	8 ounces
Potassium carbonate	375 grains

Solution B, when extreme contrast is desired:

Water	8 ounces
Potassium hydroxide	½ to ¾ ounce

To develop: Place film or plate in A for 30 seconds. Drain, but do *not* rinse. Place in B for 30 seconds. Drain and rinse a minute or so in running water, and then place in standard hypo fixing bath. After a minute or two, the negative can be examined in light from a 25-watt bulb without danger of fogging. Leave in the hypo 15 minutes, then wash in usual way. CAUTION: The potassium hydroxide solution is a bit rough on fingers, so use developing hangers or clips to handle the film while in it. With plates, Solution A can be poured out of the tray and B poured in, followed by rinsing, all without touching the plate with the hands. Solution A will keep for a long time; B should not be kept more than a day or two, and preferably should be mixed fresh each day.

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