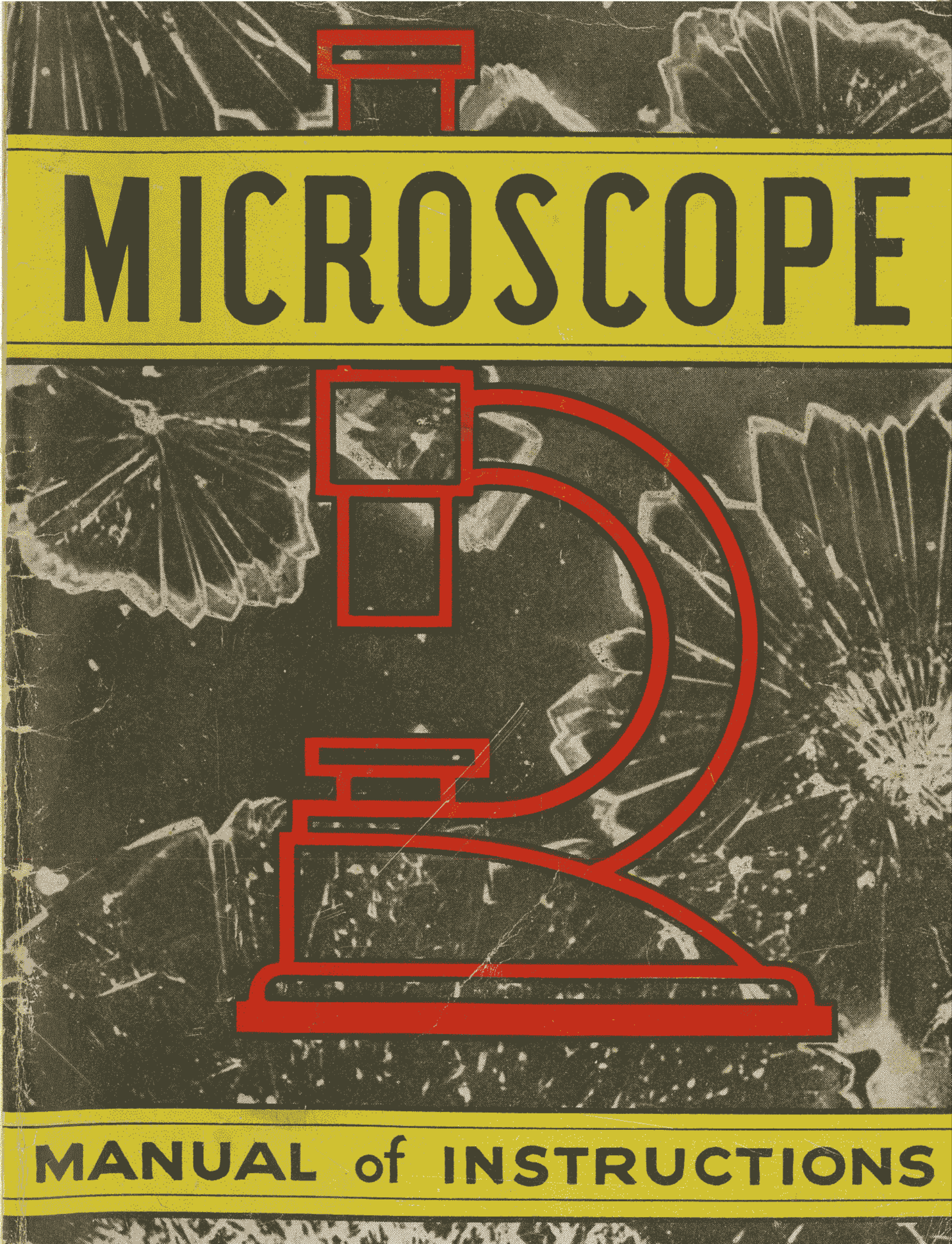

EXPLORING THE WORLD WITH THE MICROSCOPE

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TABLE OF CONTENTS

CHAPTER 6
HAIR AND THE FUR INDUSTRY

CHAPTER 7
MAKING PERMANENT SLIDES

CHAPTER 8
PREPARATION OF OBJECTS

CHAPTER 9
FUNDAMENTAL UNITS OF THE INORGANIC WORLD

CHAPTER 10
FUNDAMENTAL UNITS OF LIVING ORGANISMS

CHAPTER 11
UNICELLULAR PLANTS AND ANIMALS

CHAPTER 12
THE MANY CELLED ANIMALS

CHAPTER 13

PRINTING

CHAPTER 14

THE STRUCTURE OF THE PHOTOGRAPHIC IMAGE

CHAPTER 15

METALLURGY AND THE MICROSCOPE

CHAPTER 16

TEXTILE MICROSCOPY

CHAPTER 17

THE USE OF THE MICROSCOPE IN THE PAPER INDUSTRY

CHAPTER 18

OTHER APPLICATIONS OF THE MICROSCOPE

CHAPTER 19

DETECTIVE WORK WITH THE MICROSCOPE

CHAPTER 20
THE USE OF POLARIZED LIGHT

INTRODUCTION

Now that you own a Microscope you are equipped to undertake a journey of exploration such as you probably have never before enjoyed, for touring the world with your microscope for hidden sights is one of the most exciting pleasures that you can imagine.

Just think of the thrills there are in store for you.

Hidden mysteries and secrets of nature and science are brought to your clear vision through powerful, searching lenses and one after another amazing and unbelievable secrets are revealed.

You will see hundreds of new things — too small to find with just your eyes and you will marvel at intricate details of how things are made and put together.

You'll not only explore new and fascinating worlds but learn how to make tests, know about plants, animals, furs, textiles, paper, crystals, and do detective work as well.

The microscope, especially in this modern age is recognized as indispensable and few industries can get along without its aid.

Physicians and their assistants use it for blood counts and in examining bacteria which causes disease, scientists in making new and startling discoveries and you too can find no end of interesting objects by exploring your home and the things you and your folks use each day.

Each season of the year offers exciting experiments of its own and many of the experiments described in this manual may be performed anytime, even in mid-winter.

You will find some things which show nicely under the microscope with little care, but to really use the microscope you will wish to know how it works and how to prepare objects for examination. Even if you have used a microscope before, you will enjoy reading the first chapters of the manual and remember to make discoveries properly you should follow the directions given. Very few objects can be looked at with the microscope without some special treatment and this manual is written to tell you how to have the most fun with your new equipment. No manual, however long, could tell you of all the interesting things to see, but you will find thousands of objects all about you, at all times of the year, wherever you may be. Many people find that the microscope becomes a pleasant companion and make microscopy a delightful hobby. Years ago men either had to make their microscopes or had to pay a great deal for them, but now any boy may have a good microscope and can explore with it. Some of you may find that the microscope is necessary to your life work.

WARNING!!

This set is not intended for children who cannot read and understand the accompanying Instruction Books.

This set does not contain dangerous poisons and the chemicals mentioned in this manual are not embraced under the term "poisons." They are perfectly safe to use if handled carefully and intelligently. They are not intended to be taken by mouth or swallowed, and no intelligent person would be expected to use them for such purposes. It is necessary, however, to emphasize the fact that carelessness on the part of the experimenter can always lead to trouble. The author suggests, therefore, that all experimentation be carried out cautiously and according to the directions, especially when manipulations like heating is involved, or when gases are evolved in the reactions.

Before performing any experiments outlined in the manual, the following instructions should be read carefully and observed.

Before performing experiments, be sure to spread a thick layer of newspapers or other protective material over the table, so that hot liquids, candle grease, etc., will not injure the table.

Always read an experiment entirely through before starting to perform it. By following this rule many mistakes may be avoided.

Never point the open end of a test tube, while heating, at yourself or anyone nearby, as it may suddenly boil over, causing burns or injuring clothing. For the same reason never smell at the open end of a test tube while heating, or put your face near it.

CHAPTER 1

The Simple Microscope

Any round piece of transparent material may be used to make a simple microscope, or hand magnifying glass. No one knows who discovered the first one, but we do know that many years ago clear pebbles were used to make objects look larger. The clearer the stone the better one can see through it. Glass is used now to make magnifying glasses. The glass may be round, or one side may be flat and the other side round. All that is necessary is that the center of the glass be thicker than the edge.

EXPERIMENT 1. Using the Hand Lens

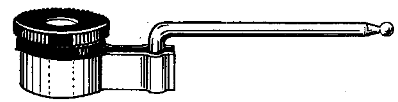


FIG. 1

Take the magnifying glass furnished in your set, fig. 1, and hold it near a piece of newspaper or other object. Bring the lens toward your eye until you find the position that gives the best view. Are the letters, or is the object right side up? Move the object while you look at it with the lens and note whether it appears to move in the same direction.

EXPERIMENT 2. Magnifying Power

Look at a hair or a small bit of wire. Compare the size of it as seen through the lens with the actual size. About how many times larger do you think it makes the hair?

EXPERIMENT 3. Magnifying Power of a Lens

A more accurate method of measuring the magnifying power is to determine the focal length of the lens. Hold a piece of white paper so that it faces a window or a light. Place the lens in front of the paper and move it slowly toward the window or light until you see a picture of the window or light on the paper. Then measure the distance from the center of the lens to the paper and this distance is the focal length. Divide 10 by the number of inches focal length and the result is the magnifying power. The lens that I have, has a focal length of 1½ inches. Therefore its magnifying power is 10 ÷ 1.5 which is just a little over six and one-half times. Everything that I look at with it appears to be nearly seven times larger.

The magnifying power depends on how curved the lens is. The greater the curvature the larger appears the object seen through the lens. Smaller lenses have greater curvature. Tiny glass beads or round drops of water make high powered lenses. Leeuwenhoek (pronounced Lay' wen huk) made many simple microscopes by grinding very small glass beads and mounting them in a hole between two pieces of metal (fig. 2). Because it was hard to hold such a microscope steady he added an arm to hold the object and arranged screws to move the object and to hold it in place. Then the microscope could be passed around and his friends could see the interesting things. He saw bacteria, small plants and animals and his discoveries were

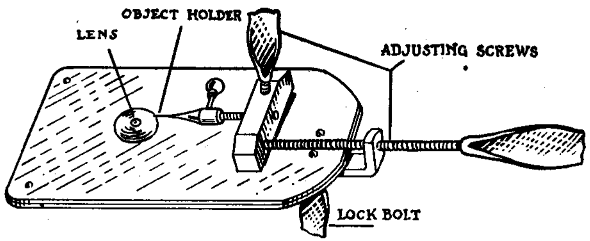


FIG. 2

so important that he used to send them from his home town, Delft, Holland, to the Royal Society in London. A great many of these little microscopes were made by him during the latter part of the seventeenth century. The one in the figure was drawn from a model made by the Bausch and Lomb Optical Co. in 1932 to celebrate the three hundredth anniversary of his birth.

EXPERIMENT 4. Making a Leeuwenhoek Microscope

Take a piece of cardboard and make a small hole through it with a nail. The hole should be less than 1/8 inch in diameter. If the cardboard is soft rub a little warm candle grease or paraffine into it to make it water proof. With a medicine dropper place a small drop of water in the hole. This is the lens. The drop should be small enough to round up. Place a fly on a pin and hold it close to the drop and look at it through the drop. You will find that the fly has to be held closer to the drop than it did to the hand lens. About how much does this simple microscope magnify? When the water evaporates it will have to be replaced. By using different sized holes and drops of water you can make similar microscopes with different powers.

The simple microscope, or hand lens, is used for preliminary examination of objects. The following experiments describe some of the observations you may make and you will think of many others.

EXPERIMENT 5. Cloth

Examine some cloth, such as a handkerchief and see how it was woven. How many threads are used to one-quarter inch? Do cloths which feel finer have more or less threads to the quarter inch?

EXPERIMENT 6. Finger Tip Patterns

Examine the ridges on your finger tips with the hand lens. Do they all have the same pattern? Are they the same on your friend's fingers?

EXPERIMENT 7. Finger Prints

If you have a stamp pad place a finger on it to cover it with ink and then place it on a piece of paper to give a finger print. If you do not have a stamp pad rub off some lead from a pencil and use it instead of the pad. Compare different finger prints using your lens.

EXPERIMENT 8. How Printing Appears

Look at different kinds of printing to see if the letters are equally clear. Look at a bit of colored "funny" paper and see how the colors are printed. Some will be plain color and others made by printing dots of a different color over the first color. The dots seem to blend with the plain color when seen by the unaided eye.

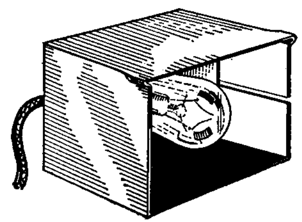
EXPERIMENT 9. Printed Pictures

Compare pictures made on good paper in a magazine with those printed in a newspaper. You will see that the picture is actually printed as dots and the coarser the paper, like newspapers, the coarser are the dots and the less clear the picture details become.

EXPERIMENT 10. Some Interesting Experiments

Minerals, frost on the window pane, crystals, dust, etc. will be interesting subjects when seen under your hand lens. In fact any object that can be brought into the light becomes more interesting under the magnifying glass. Be sure to look at plants, flowers, insects, etc.

SUBSTAGE LAMP



One of the most important things to watch out for in using the microscope is proper lighting. Improper lighting not only endangers the eyes but decreases the efficiency of the instrument.

The substage light is intended for use on dark days, night or in dark rooms. Its advantage lies in the fact that the amount as well as the direction of the light can be controlled. Place it directly in front of the microscope and as near to it as possible. Turn the substage mirror until the bright light covers the field evenly and smoothly as you look into the microscope. Now move the lamp straight away from the scope until the light is just comfortable for the eye and produces no uneasiness nor strain. This is the proper position for ordinary use. If certain specimens appear dark move the lamp toward the microscope until the specimen can be easily seen. For opaque specimens the lamp may be placed on a small box or pile of books and directed down upon the specimen.

Remember! Never under any circumstances use direct sunlight, and try to cultivate the habit of observing with both eyes open.

CHAPTER 2
The Compound Microscope

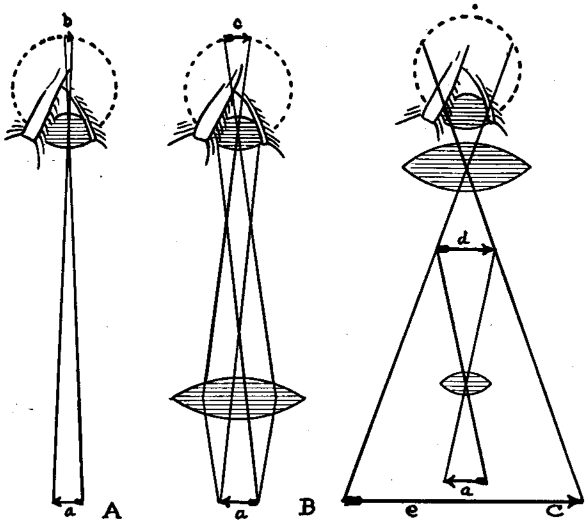


FIG. 3

The Janssen brothers discovered in 1590 that a second magnifying glass might be used to magnify the image of the first lens and the combination of lenses is the compound microscope. You found how a lens gives an image in experiment 4. In this case the image was smaller than the object because the object was far away from the lens. When the object is closer to the lens the image is larger. The image of the first lens becomes the object of the second lens in the compound microscope and the doubly enlarged image of the second lens is seen by the eye.

An object such as the arrow a in fig. 3A is visible because it reflects light into the eye and the eye forms an image b on the retina or sensitive region inside the eye. This image b is not very large and we would say that the object seen was small. Now if we look at the same arrow a with a magnifying glass as in fig. 3B the image of the arrow c on the retina of the eye is larger and the greater size is the amount it is magnified. With the compound microscope the arrow a is magnified by the first lens to an image of size d. The image d is further magnified by the second lens and because this lens is close to the eye the image appears to be located below and of the size e.

Two lenses, both thicker at their centers than at their edges, properly arranged at the right distances in a tube make the compound microscope; and in fact, the first one did look more like a telescope. However, it was tiring to hold this kind of a microscope in the hand because the least movement caused the image to disappear. Many improvements have given us the present microscope and different kinds of microscopes are made for special purposes.

Most of the objects that one wishes to see in detail are either transparent or may be prepared thin enough to be clear. Therefore, the microscope must have a stage to hold the object with a hole through the stage so that light may be thrown onto the object by an adjustable mirror placed below the stage, fig. 4. The tube containing the lenses of the compound microscope is held above the center of the stage in a ring so that it may be raised and lowered. In the larger microscopes the tube with the lenses, called the

body tube, is moved up and down by a rack and pinion gear turned by the wheels at the side. This gives smoother movement and better control.

The early microscope makers soon found that if a third lens is placed near the eye lens the object appears to be brighter. The third lens is usually placed in a tube with the second lens which is called the draw tube. Both lenses together are called the ocular, or the eyepiece, to distinguish them from the first lens. The first lens nearest the object is called the objective. The different parts of the microscope are marked on fig. 4. The magnification of the microscope can be increased by pulling out the draw tube so that the eyepiece lenses are farther away from the objective or decreased by pushing in the draw tube.

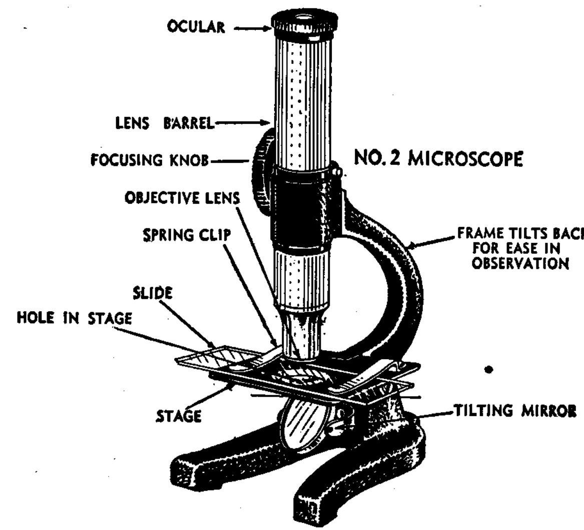


FIG. 4

You may ask why two compound microscopes should not be combined to get a still greater magnification by letting each magnify the image of the one in front of it? This may be done but each lens takes some of the light passing from the object to the eye so that if too many lenses are used the object becomes invisible due to a lack of light. Occasionally two microscopes are used together as a stunt but for greater magnification it is better to use a microscope with stronger lenses.

What is the limit of magnification you will ask now? The limit is set by the nature of the light that is reflected by or passes through the object, and the sensitivity of the eye. With the best microscopes the smallest object that may be seen as it is, would be about one one-hundred and thirty thousandths of an inch (1/130,000). The practical limits seeing with the microscope are about 1500 to 2000 times magnification. By the use of ultra violet light and special photographic plates a greater magnification may be obtained. To use these high powers one must have expensive instruments but they are only required for special work and the ones in your set will show you many of the wonders of the world of small objects.

Now it is time to use the microscope. Take it out of the set and unwrap it carefully. Dust off the mirror, the bottom of the objective and the top of the ocular with lens paper or very soft cloth, being careful not to scratch their surfaces. Glass used in microscopes is softer than that used in windows and must be treated carefully. Place the microscope in front of you on a table of convenient height facing a window and turn the mirror until you can see an even, bright field as you look into the ocular. Tear out a few letters of a newspaper and put them on the stage above the opening. Lower the body tube until it nearly touches the object as you look at it from the side of the microscope, and then as you look through the microscope gradually raise the body tube until you see a letter or part of a letter clearly. As you raise the body tube it will first be blurred and then gradually clear. If you raise it a little too far it will become blurred again and you will have to lower it until it becomes clear. Moving the tube until the object is seen at its clearest is called focusing the microscope.

EXPERIMENT 11. Reversal of Image by the Compound Microscope

Focus the microscope, as described in the last paragraph, on a letter. Move the letter to the left and see whether it seems to be moving to the right. Move it away from you and it appears to move toward you. Is the letter upside down and wrong-side-to? The compound microscope reverses the image. This is shown by the reversed arrow image in fig. 3C e. You note that the least movement will push the object so far that it disappears from view. A little practice will soon teach you how to move the object yet keep it where you wish it.

EXPERIMENT 12. Making a Temporary Slide

Clean one of the large glass slides and one of the small cover glasses with a little soap and water and wipe dry with a clean cloth that does not leave lint. The cover glass must be handled very carefully as it must be made thin and is easily broken. If you put it on a cloth on a flat surface it may be rubbed without breaking. Should you break the first one save the pieces for use later. Pick out a bit of newspaper which has small letters printed on only one side of the page and just large enough to have a few letters. Place this at the center of the slide and a drop of uncolored oil on the paper and then place the cover glass on by gradually laying it down from one edge so as not to get in air bubbles. If air bubbles should form take off the cover glass and clean it, add a little more oil and try again. Examine this slide with the hand lens and note how large the letter appears. The oil makes the paper translucent so that the light passes through it easily.

EXPERIMENT 13. Adjusting the Mirror

Turn the mirror slightly to one side and notice that the object appears to sway from side to side as you focus the microscope. The light should always be centered so that the object does not sway as you focus up and down. Always have enough light to see with clearly but not so much light as to glare. Never use direct sunlight as it is much too bright. With clear objects you will need less light and with dense objects more light.

EXPERIMENT 14. Locating Dirt on the Microscope Lenses

When the mirror is dirty you cannot get enough light to see well. Place a piece of paper over the mirror and you will see how much light you lose. When the objective is dirty you cannot focus the microscope clearly and everything looks like it was in

a fog. The same happens in case a drop of water gets on the objective lens from a wet preparation. Should this happen carefully wipe the lens dry with a soft paper. Dirt on the ocular appears as specks and you can easily determine this, because if you turn the ocular around as you look through it the specks will turn too. Wipe off the top of the ocular and if they still show wipe off the bottom. When through working for the day clean the microscope and either cover it with a clean cloth or put it into the case so that it will keep clean.

CHAPTER 3

Care of the Eyes When Using the Microscope

You have two eyes so do not expect one to do all the work of looking through the microscope. Use one a while and then the other. All skilled microscopists keep the eye that is not looking through the microscope open, because it does not tire one nearly so much as when the eye muscles must work to keep that eye tightly closed. Learn to keep both eyes open and to see with only one through the microscope. At first it seems hard but you will very soon learn not to notice what the other eye sees. Sometimes it helps to hold the hand in front of the eye and gradually take it away. When using mounted objects the microscope may be tipped back at the joint just below the stage to a convenient angle.

Plan to be comfortable when you work. Have a table of the proper height so that you do not need to stretch your neck or try to fold yourself up like an accordion. If the table is not the right height place a box on it, or better, set the legs on boxes to raise it. With the electric lamp you may work anywhere that you can connect it into an electric outlet. When you are using daylight it is better to use a north window out of the direct sun and arrange the window shade so that the light is kept from hitting you in the eye.

If you habitually wear glasses it is better to keep them on when you are using the microscope for any length of time. It is not as convenient but many people learn to do it. It is especially important if you have any astigmatism. If you are just near or far sighted you may take your glasses off safely and correct for them by focusing the microscope to your own eye.

EXPERIMENT 15. Determining Whether or Not Your Glasses Are to Correct for Astigmatism

Take your glasses off and hold them a half to an arms length away and look at a window, a picture or other square object. Turn the lens around and note whether the object remains square or whether it seems to become lopsided as you turn the lens. If it does not remain square it will be better to wear your glasses when you use the microscope.

When one is in a comfortable position, both eyes are open, the lenses are clean, and the light is adjusted so that clear vision is possible with no glare, you may use a microscope for several hours at a time without discomfort. Most people like to get up and move about for a few minutes rest during long periods. The eyes should be changed at regular intervals. The microscope properly used never gives one a headache, but if one gets a headache it suggests that the reason for it should be found and corrected.

CHAPTER 4

Observations and Records

Microscopists keep records of their observations and experiments, so that they can use them at a future time. The detective must have records as he cannot remember the appearance of everything he has examined. The best way to keep a record of what you do with the microscope is to have a note book which is used for nothing else. Loose-leaf books can be bought very cheaply with ruled pages for notes and plain pages for drawings. Or a bound book may be your choice.

The first thing to do in making a record is to write the date and where you are working. Then an answer to the question why did you decide to look at that particular thing with your microscope. How did you prepare it and use it? wet or dry preparation? natural or stained with dyes? What did you see?

The answer to the last question may be done more easily with a simple drawing or sketch. At first you may think drawing is difficult but simple sketches, like many of the illustrations in this manual, are easily made. At first it may help to make a circle about two or three inches in diameter in your book and then to draw into that the appearance of the object. A circle may be made with a compass or tracing around a small glass jar or other round object. First, what is the general shape of the object? A hair would be outlined by two lines. A small animal might be like an oval, in which case you would lightly draw an oval and then change the outline to look like the animal. Usually only enough detail is drawn to show the character of the object—perhaps filling in only a strip across the drawing. For the hair a narrow strip shows how it is made and as the rest of the hair is just the same there is no use drawing any more. If a pattern, or kind of structure is just repeated, we usually only draw the pattern once and then indicate by crosses where it appears also. Note the features that are characteristic. They are the details you will want to know later. All hairs look much alike to the eye but just how do they differ when seen under the microscope? Those differences will be necessary in case you are given or find a hair and must find out with your microscope whether it is a human hair or a dog's hair. These special features may be indicated by drawing them in heavier line, pointing an arrow to the critical features or writing a brief description of them.

The object of making the record is its use tomorrow or perhaps a year from now. Before you stop, read your record through and ask yourself, is this information all that I will need to know later, or when I read this later will I be puzzled by its not being quite complete enough? A good record contains the story of your experiment with enough detail so that you can refresh your memory from the story without having to find and look at the object again.

CHAPTER 5
Collecting and Storing Material

You may collect material to look at with the microscope everywhere. If you are near a pond or creek, a cleaned screwcap bottle, like mayonnaise comes in, will be useful for bringing back some of the material. Dry materials may be put in tobacco tins, envelopes, small paper bags or boxes. When it is raining you may collect in the house. A little dust from the vacuum cleaner, starches, flour, etc. from the pantry, bits of different kinds of paper, etc. The important thing is to label each specimen clearly as to what it is and where and when you collected it. Sometimes you can write on the outside or stick a label on the outside of the container and write on that. When that is not possible, write the label on a bit of white paper and put it in with the sample. A soft pencil should be used rather than ink because the pencil will not blot should it get wet.

The microscopist keeps small amounts of materials for future reference. You probably remember reading about Sherlock Holmes' collection of soils and of cigar ashes. It is often necessary to compare an unknown object with a known one to be sure that they are the same kind. Sometimes the specimens are mounted as permanent slides, as you will be told about later, and sometimes the samples themselves are kept. Very little material is necessary for a microscopic examination. That is why the microscope is being used so much in chemistry and many industries.

A collection is more useful and looks better if the different samples are well arranged and kept in a box in one place and not scattered throughout the house. A sample is of no use unless you can find it quickly when you want to use it. Dry samples may be stored in envelopes, pill boxes or other small containers. These may be saved as they come to the house or may be purchased quite cheaply at a wholesale drug store. Many specimens may be kept in gelatin capsules with a label in each and the capsules arranged in rows in a box. They may be obtained in convenient sizes from very small to about an inch long. Chemicals that are apt to get damp should be put in small bottles or vials. Some living materials may be dried and kept that way but others must be specially preserved in alcohol or formalin and these special methods will be given as we study the specimens.

Some specimens, such as snowflakes, cannot be saved and one must depend on the record book or photomicrographs to show how many kinds there are and how they are made.

CHAPTER 6
Hair and the Fur Industry

Hair is a convenient object with which to start microscopic study. The hair is not composed of living cells but increases in length as the living cells in the skin at the base of the hair add to it. These cells are in a sort of pocket called a follicle in the skin and as they increase in numbers the extra cells are attached to the inner end of the hair. Except for gray hair pigment is added to the cells as they change and harden into hair. Most hairs have a central canal, or medulla, and the outside of the hair is scaly when highly magnified. The size, and shape of the hair and the kind and arrangement of the scales are characteristic of each kind of mammal and make possible the identification of the fur.

At the base of the hair is an oil gland which forms an oily protective secretion which helps prevent the hair drying and cracking. The oil and any dirt that the hair may have accumulated cover up the fine markings on the hair. Before looking at the hair it should be cleaned by moving it about with the forceps Fig. 5C in a

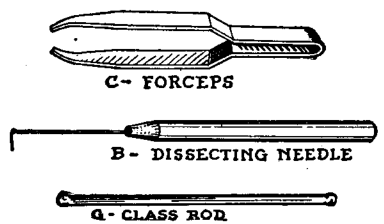


FIG. 5

little alcohol. If the hair is long it may be scrubbed in soap and water and then washed free of soap. A short piece is cut and put in water under a cover glass on a slide for study under the microscope.

EXPERIMENT 16. A Brunette Human Hair

Take a small bit of a dark hair, clean it and mount it and look at it with the low, medium and high powers of the microscope. Knowing the actual size of the hair as seen without the microscope its apparent size under the different lenses will help you realize how much the microscope magnifies. The central canal is surrounded with a layer of material containing the pigment granules which give the color to the hair. On the very outside is the layer of scales.

When you look at dark hair you will need to have plenty of light to see with. The microscope lamp will help if the daylight is not strong enough. If you still have difficulty, dry the hair with a little absorbent paper and study in a drop of xylene.

EXPERIMENT 17. A Blonde Hair

Obtain a hair from a blond person and notice that there is a yellowish pigment in the layer around the canal, i.e., in the medulla.

EXPERIMENT 18. A Gray Hair

The gray hair from an older person is found to be light colored because it has no pigment, or very little pigment in the medulla. The follicle is no longer putting pigment granules into the cells as it turns them into hair.

EXPERIMENT 19. A Red Hair

In pure red hair you will find very little of the dark pigment but reddish to yellowish pigment occurs.

EXPERIMENT 20. Straight Hair

Take a piece of naturally straight, uncurled hair and cut off as thin a section as you can with a very sharp knife. A safety razor blade makes a good knife. It is better to use the kind that has only one edge so as not to cut your fingers. It may help to place the end of the hair in a drop of water on the slide and cut the sections in the water. Make a number and then place a clean cover glass on the drop. Examine one that is thin enough and so placed that you can make out the cross section. You will find that this is nearly round or circular.

EXPERIMENT 21. Curly Hair

Prepare a bit of naturally curly hair as you did in the last experiment and it will probably be flattened so its cross section will be oval.

EXPERIMENT 22. Permanent Waving of Hair

Permanent waving of hair causes the hair to curl by artificially flattening the hair strands. When you examine thin sections of hair that has been waved you will find that they are more or less oval but that the strands are not so uniformly flattened as in naturally curly hair.

The hair of our animal friends is just as interesting and of commercial importance. Wool from the sheep, fig. 6, is very important and will be discussed later (Chapter 16) with the textiles.

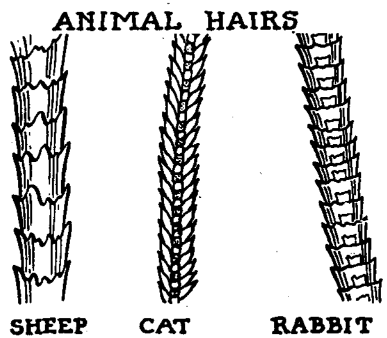


FIG. 6

EXPERIMENT 23.
Examine a Bit of Wool

The central canal is less easily seen and the surface is covered with irregular scales. Different kinds of wool may be known from the nature of these scales.

Only one or two fine hairs are necessary for identification with the microscope and they may be obtained from a seam or the end of a tassel without injuring the cloth or object from which they were taken. This is one of the reasons why the microscope is so useful and important.

EXPERIMENT 24. A Cat Hair

A cat hair will look like the one in fig. 6. Different kinds of cats will have slightly different kinds of fur.

EXPERIMENT 25. A Dog Hair

A dog hair is different from a cat hair and from our own hair. Examine one. What is the chief difference? If you have looked at a number of samples of hair from different kinds of cats and dogs can you tell from which an unknown hair might come?

Your note book records are very valuable as soon as you start identifying unknown hairs. Even with a good notebook you will wish to have some samples of known hairs with which to compare any unknown ones. The bits of cleaned hair may be kept in envelopes or in small gelatin capsules. Or you may make slides of each kind and keep the slides as described in the next chapter.

EXPERIMENT 26. A Rabbit Hair

A rabbit hair should look like the one in fig. 6. Rabbit fur is cleaned and dyed various colors and sold in the stores under a lot of other names like mock-fox, lapin, imitation seal, etc. It is against the law to call rabbit fur, seal, but other names are used. Other furs are sheared to change the length of the hairs and dyed to imitate more expensive furs. However, the shearing and dyeing cannot change the structure of the hair and the microscope comes to the rescue of the fur buyer when there is any doubt. If you are interested in furs obtain small samples, a few hairs of each are plenty, from a fur dealer and learn to recognize the different kinds under the microscope. You can usually get a few hairs from the cages of animals at zoological gardens if you will tell the keeper why you want them. Good sketches in your note book will help you when you must identify an unknown hair; but a good microscopist will make a direct comparison with a known hair before giving his answer.

EXPERIMENT 27. Identifying a Hair

The next time you pick up a hair examine it with the aid of your microscope. Is it a human or an animal hair? Has it been curled artificially or is it naturally curly? etc.?

An alert policeman noticed some dirt on a dented part of the fender of an automobile. He sent the material to the laboratory and was told it contained human hairs. This one clue led ultimately to the conviction of a man who had run down and killed two children.

CHAPTER 7
Making Permanent Slides

The slides which we have looked at so far were of objects in water between the slide and the cover glass. These will not last because the water will dry out. When a drop of glycerine is used instead of water it will last much longer, but it is not a permanent preparation because the cover glass could be easily pushed off.

A drop of white Karo corn syrup makes a good mounting medium which partially dries and holds the cover glass fairly well.

For really permanent slides the material is cemented between the slide and the cover glass with balsam or dammar. Both are gums from the sap of certain trees. The pitch is dried and then dissolved in xylene for use by the microscopist. The one difficulty in using balsam is that the material to be mounted must be dry, because the balsam will not mix with water and the tiniest drops would appear like a fog when placed under the microscope.

For material which may be dried in air without injury like the hair samples you have just been examining, all that is necessary is to blot off the excess water on the slide and let the material stand until it is dry. It is a good plan to warm it gently just before mounting but one should be careful not to cook the material. Slight warming over a radiator, or an alcohol lamp, is all that is necessary. Then put on a drop of balsam and gradually lower a clean cover glass held with the forceps so one edge first touches the drop and then until the whole glass is on the drop. This way will aid in keeping out air bubbles.

A little practice will soon teach you how large a drop is necessary to just fill the space between the slide and the cover glass. If you get too much let the slide dry and then carefully scrape off the excess with a knife. Should you not have enough add a small drop to the edge of the cover glass and it will run in and fill the space. Straighten the cover glass with your forceps or a dissecting needle so that it is square with the slide and then put the slide on a flat surface where it will not be disturbed, or get dusty, until the balsam gets hard; which will take from a few to many days depending on how warm the room is and how much balsam you have used.

When the slide is dry use a knife to trim off any excess balsam from around the cover glass and wipe it with a little xylene on a soft bit of cloth. Paste a label on the left hand side of the cover glass and write, with ink, what the object is; what stain was used, if any; any special information you have; the date and your name or initials. If you have a record in your note book you can give the record and the slide the same number. Print your labels neatly and you will soon have a set of slides to be proud of, for your own use and to show your friends.

EXPERIMENT 28. Making a Permanent Slide with Karo Corn Syrup

Clean and dry some short lengths of hair and mount them in Karo corn syrup and set aside for a week to dry.

EXPERIMENT 29. Making a Permanent Slide with Balsam

Mount some of the hairs in balsam and set aside to dry in a place free from dust for a week.

At the end of a week examine both slides. Which seems to be the best method for making permanent slides? Clean and label each for future use. The slides in Karo syrup should be stored flat until they are well hardened or else the preparation will run.

CHAPTER 8
Preparation of Objects

Many of the objects that we wish to examine with the microscope are much too large and require special treatment before they may be seen to advantage. Certain specimens are prepared by methods adaptable to them and many of these will be given in various parts of the manual. However, there are some general methods which are used so frequently that we should learn them before continuing our experimenting.

Sifting material like grain, spices, foods, soils, etc., through a series of sieves of increasing fineness is one of the commonest methods used to get material for study with the microscope. Insects are separated from flour, when it has been infected, by an ordinary sieve like your mother uses. Very fine sieves are used for special purposes, and the finest of them are made of silk cloth called bolting cloth.

EXPERIMENT 30. Sifting

Sift a little whole wheat flour through a flour sieve or a fine screen and note how many kinds of particles you find.

Minerals, rocks and other hard materials must be crushed before they are looked at under the microscope and after crushing the particles are separated according to size with a screen. The crushing must not be too complete or the essential structure will be destroyed so that it will not be possible to recognize the material.

EXPERIMENT 31. Crushing and Sifting

Crush some of the particles that you found in the whole wheat flour and sift again. What seems to be the main difference between whole wheat and ordinary white flour?

EXPERIMENT 32. Kneading

Kneading is really a sifting process done under water. Place a little flour in the center of a square of muslin or calico cloth and fold the ends together so as to make a sack. Fill a small pan nearly full of water and then put the bag of flour under the water and gently knead it until the starchy part of the flour has been forced through the bag into the water. Examine the starchy water. The gluey part of the flour, the gluten, has been separated from the starch.

Are the starch grains all the same size? To separate the grains of different size we use a process called sedimentation.

EXPERIMENT 33. Sedimentation

Fill a tall glass with the starchy water from experiment 32 and let the starch settle out. The larger particles sink to the bottom first and the smallest last. After the glass has set until the liquid begins to clear at the top, take a drop with your medicine dropper from the surface of the water and place it on one end of a clean slide, place another drop from the center of the glass in the middle of the slide and place a drop from the bottom on the other side. After putting a cover glass on each look at them under your microscope and see to what extent they have been separated according to size.

Some substances are less dense than water and float on it. Other substances are heavier and sink. By choosing a liquid of the right density one can make any material float or sink and this way we can use sedimentation to separate materials so that we can examine them separately.

EXPERIMENT 34. Separation by Special Mixtures

Into a tall glass put two small glassfuls of glycerine and one small glass of water. Stir until they are well mixed. Then stir in some ground coffee. The coffee will rise to the surface after you stop stirring, but if any chicory is in with the coffee it will sink to the bottom. Coffee is sometimes adulterated with chicory and it would be tiresome to examine each grain under the microscope to see which it was. Separating them in this solution then makes it possible to quickly see and identify the chicory when it is present.

Sedimentation is often a slow process and in some laboratories a centrifuge is used rather than letting the material set in tubes. In this machine the tubes of material are put in a wheel and whirled rapidly. The faster the machine is run the quicker the material settles. A glass shaped like an ice cream cone with a base to hold it up is used for sedimentation as it is easier to pick up small particles from the narrow bottom.

EXPERIMENT 35. Obtaining Rice Facing

Shake a little rice in a small glass of water and then pour off the water into a second glass and let the material settle. Pouring off the milky water from the rice is called decantation. After the sediment falls to the bottom examine a drop of it on the microscope to see if it is all starch.

EXPERIMENT 36. Starch or Talc?

If some of the granules do not seem to be starch add a drop of iodine and the talc if present will not be stained blue like the starch. If you wish to make certain, purchase a little talc from the drug store and compare the known talc with the sediment from your experiment.

EXPERIMENT 37. Sampling Soil

Shake up a little soil from your yard with water in a small glass or test tube and after only a moment of settling pour the muddy liquid into another test tube or glass. Continue this two or three times. You have now elutriated the soil into samples of different kinds. For the finer particles this method is better than sifting, but in soil examinations the coarser particles are sifted out first and the finer ones separated by elutriation.

Oily substances are used as clearing agents to help us see different kinds of things in a mixture. If you have a little self raising flour in the house you know that it must have chemicals like baking powder in it to make the bread of pancakes raise. If you look at it as it comes from the package you cannot see these chemicals very easily in the dry powder. If they are washed out by kneading they go into solution and disappear. The best method to see them is to clear the rest of the preparation with oil.

EXPERIMENT 38. Clearing with Oil

Place a bit of self-raising flour on a clean slide in a thin layer. Put on it a drop of clove oil and then the cover glass. The starch of the flour becomes nearly transparent so that you can hardly see it but the crystals of the chemicals are now cleared so you can see them.

Various oils can be used like paraffine oil or even machine oil. In the study of foods cresol is used as a clearing material. The cresol is sometimes mixed with an equal amount of glycerine. Should you purchase any cresol from a drug store be careful not to get it on your skin as it will make it burn. Should you accidentally get some on you wash it off with water and then wash with rubbing alcohol. The alcohol destroys the cresol.

Oily materials are usually examined in an oil preparation.

EXPERIMENT 39. Mounting in Oil

Put a little ground mustard in a little clove oil on a slide and examine the particles with your microscope.

Materials that will dissolve in water can be obtained from a mixture by filtration.

EXPERIMENT 40. Filtration

Shake up a little self-raising flour in a test tube or glass partly full of water. Fold up a piece of fine absorbent paper such as a thin blotter or a piece of paper towel, like a cone, fig. 7 and pour your material into it. The water will pass through and may be caught in a test tube or a glass and the starch and other insoluble matter will be kept in the paper cone. Put a drop of the liquid on a slide and let it stand until it dries. Any chemicals present will crystallize out and may be seen under the microscope.

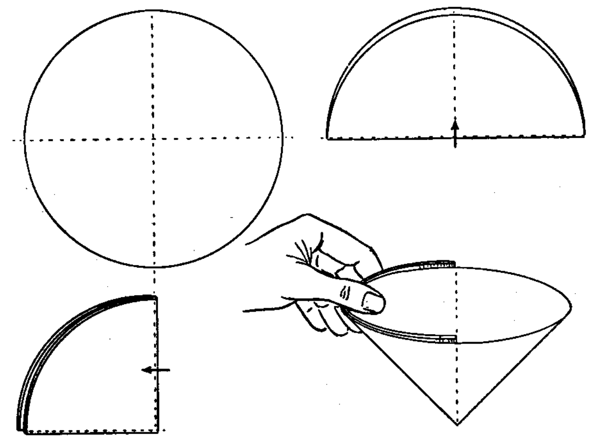


FIG. 7

Other solvents than water may be used to advantage in microscopic work and by the application of chemical methods many materials may be identified. The use of these methods is especially important in testing foods, drugs, and other substances for adulteration by less nutritious or cheaper materials.

When we want to look at parts of plants and animals that are too large to use under the microscope other methods are required. Sometimes simple dissection is adequate such as breaking off the leg of a dead bee so that the leg may be easily seen with the microscope.

Teasing is done by holding a bit of material in a drop of water on a slide with a dissecting needle, fig. 5B, in one hand and pulling it apart with the other dissecting needle in the other hand.

EXPERIMENT 41. Teasing Paper Specimens

Gently tease a bit of paper to separate the fibers so that they may be seen with the microscope.

EXPERIMENT 42. Teasing Meat Fibers

Tease apart the fibers of a bit of raw, lean meat until you can see them separately under the microscope, fig. 8B.

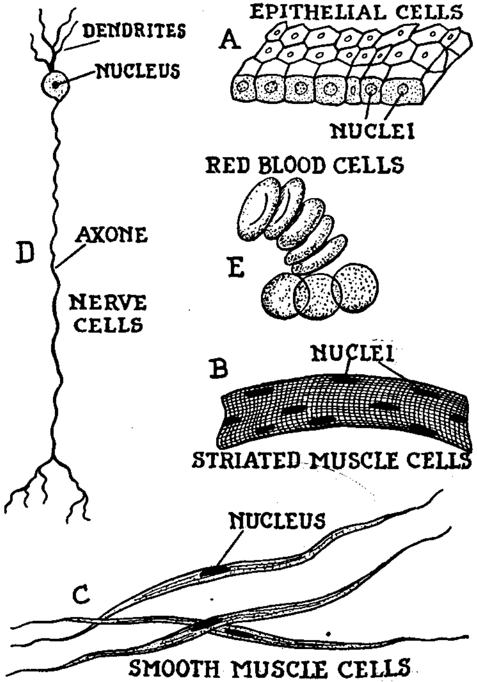


FIG. 8

EXPERIMENT 43. Teasing Potato Cells

Tease a bit of potato and examine it with the microscope. Add a drop of iodine, that can be obtained in any drug store, which will stain the starch blue or blue-black depending on how much you use. It is better not to use too much stain in microscopic work because if the material is too stained not enough light passes through it for the eye to see. Is the teased potato all starch? or are there bits of other material?

CHAPTER 9

Fundamental Units of the Inorganic World

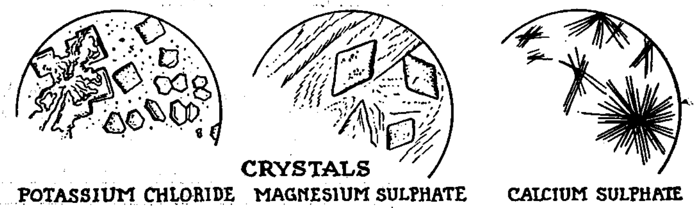


FIG. 9

The inorganic world is composed of rocks and all materials not part of living or dead organisms. The inorganic material is found in three states, gases, liquids and solids. These are composed of units, molecules, so small that they cannot be seen with the microscope. Solids are built up of crystal units in a definite pattern according to the kinds of units involved and these patterns can be seen with the microscope even though we cannot see the individual molecules themselves. A molecule is the smallest part of a pure substance. If it is divided any further it is broken up into the materials of which the molecules are made.

Most solid materials form crystals and even non-crystalline materials like rubber, glass, etc. have a definite structure which can be shown under proper conditions. The crystal can be thought of as the unit of the inorganic world and special instruments like the X-ray and the spectroscope show what the structure of the crystal is and how the crystal is built. Many materials used in living plants and animals have equally definite structure and the same methods are used for their study.

There are many kinds of crystals. Besides the square type that you measured of salt, some form needles, others branches or dendrites, plates, etc., fig. 9.

EXPERIMENT 44. Dendrite Crystals of Aspirin

Dissolve one-half of an aspirin tablet in about a tablespoonful of water. Let any solid matter settle and place a drop of the clear fluid on a slide. Watch the growth of branched, dendritic crystal as the solution dries.

EXPERIMENT 45. Starch Test with Iodine

If there is a sediment left look at a little of it under the microscope and try staining it with a small drop of iodine. Does the material look like starch? Many pills and tablets have some starch in them as an inert material giving body to the tablet.

EXPERIMENT 46. Crystal Growth

Dissolve as much sugar as you can in a teaspoonful of hot water. Take a little of this and dilute it with as much cold water. Place a drop of the strong and of the diluted solution on a microscope slide and note how fast the crystals grow and from which drop you get the largest and more perfect crystals. Usually larger and more perfect crystals grow in dilute solutions.

CHAPTER 10
Fundamental Units of Living Organisms

The cell is the fundamental unit of living organisms. Hooke in 1665 examined some thin sections of cork and found that it was formed of small open spaces which he called cells, because they resembled somewhat the cells of the monasteries.

EXPERIMENT 47. Cork Cells

Repeat Hooke's discovery by making some thin sections of a cork and examine them for cells with first the low and then the higher powers of your microscope. Are the cells the same size and shape when you make the section lengthwise of the cork as crosswise? Another way to obtain a thin section of cork is to soak off the cork from a cork tipped cigarette and use it.

It was soon discovered that these open spaces in cork were not typical cells. Most cells are full of living and stored materials, but when the cork was formed in the bark of the oak tree the cell contents were used up to make the heavy, waterproof walls of the cork cells and that is why they are empty.

EXPERIMENT 48. Cells from Celery

The cells in the outer layer of celery make good objects for microscopic study. Insert the end of a small knife into the inside of the celery stalk a very slight distance. Hold the skin of the celery against the knife with your thumb or finger nail and strip the skin off by pulling upward. Place the piece on a clean slide in a drop of water and cover with a cover glass. Examine the edges of the preparation under your microscope until you find a place where the cells seem to be only one layer thick. If your first preparation is too thick to show a single layer of box like cells try again.

The celery cells are not empty but contain a jelly-like material called protoplasm. In the protoplasm you will see a round body which is the nucleus (nuc' le us) or the controlling center of the cell. Within the nucleus you may see another round body, the nucleolus (nu cle' o lus). The protoplasm may contain ganules and in healthy normal cells fills the cell completely. The walls of plant cells are thicker than those of animal cells and usually composed of cellulose. Absorbent cotton is nearly pure cellulose obtained from the seed hairs of the cotton plant.

If the water in the protoplasm is lost the protoplasm shrinks and when this happens in many of the cells of a plant the plant wilts or becomes flabby. By the use of strong chemical solutions it is possible to draw the water out of the protoplasm.

EXPERIMENT 49. Plasmolysis of a Cell

Dissolve a small amount of sugar in a drop of water. Transfer this to the celery cell preparation and run it under the cover glass by touching the other side with a bit of blotting paper. Watch the cell under the microscope and in a little while you will see the protoplasm begin to shrink away from the cell wall. When this happens run fresh water under the cover glass and see if the protoplasm again swells to the size of the cell. If the shrinking has not been too complete recovery takes place. That is why mother puts the vegetables into water before they are served.

EXPERIMENT 50. Sugar and Salt Solutions

Try different strengths of sugar solutions and of salt solutions and see how the rate of shrinking is related to the concentration of the solution. If you have some Spirogyra (chapter 11) it makes a very good subject for these experiments.

The flow of water from the protoplasm into a stronger salt or other chemical solution is called osmossis and the regulation of it by the cell keeps its pressure to proper levels. If the difference between the inside and the outside of the cell is too great the cell cannot properly regulate its own pressure and is killed. Too much chemical fertilizer kills the cells in the plant roots. If cells from plants living in the ocean are put in fresh water the flow of water is into the cell, the protoplasm is more concentrated in these cells, and the cells swell up and burst.

Besides the thicker cell wall plant cells often have green material in their cells. The green is chlorophyll (chlor' o fil) and is used by the plant to trap the energy of sunlight for the process of food making. Because of this pigment plants can make foods out of simple mineral salts, water and carbon dioxide gas. Animals do not have this pigment and must depend on the plants for their food stuffs. Some plants, like the bacteria and molds, lack the pigment and are likewise dependent on other plants for food. The green pigment is usually to be found in certain parts of the cell called chloroplastids (chlor' o plas'tids) rather than being scattered throughout the cell.

EXPERIMENT 51. Animal Cells

Make a slide of cells from your mouth and note that the animal cells have very thin walls, so thin that it only is a surface of the cell fig. 8A. No chloroplastids are seen. Does the protoplasm look like that you saw in the plant cells?

The fundamental living material or protoplasm is the same in both plant and animal cells and the cell is the fundamental living unit. Some plants and some animals consist of only a single cell, while other plants and animals are composed of many arranged.

The shape of cells is interesting. When the cells grow freely and are not under any special strain they are made so that the wall has the least amount of material in it. Such cells have fourteen sides of which four are squares and the rest are hexagons, (six sided). Such cells stack together and fill the space closely.

EXPERIMENT 52. The Form of Soap Bubbles

Fill a drinking glass with soap bubbles and note the shape of the bubbles that touch each other but do not touch the glass. Most of the surfaces are hexagons. The wall of the soap bubble is elastic and tends to shrink until it takes the least size and this least size gives the hexagonal form like that of the cells described in the last paragraph. Instead of the form being due to economy as in the plant it is due to the surface tension of the soap bubble.

EXPERIMENT 53. The Cells in Onion

Examine a little of the skin of the inner leaves of an onion bulb to see what shape the cells are. Try other plant tissues.

The method is to cut sections and measure them and then do the same at right angles to the first sections. By combining these in a sketch in the notebook a record of the shape of the cell is obtained. When cells do not have hexagonal cross sections we know that more than the least amount of material must have been built into the cell wall and the cell has to spend energy in making and maintaining its wall. We can get some ideas of this by comparing the shapes of different kinds of cells. Many plant cell walls are stiffened with cellulose and the wood is formed by the cellulose being changed into lignin, which is the chemical name for the woody substance. Animal cells also strengthen the cell wall with various materials.

A typical cell consists of protoplasm, the basic living material surrounded by a cell wall or membrane, fig. 10. In the protoplasms is the nucleus which is the controlling center of the cell. A nucleolus may or may not be present. In many plant cells the chlorophyll is found in variously shaped chloroplastids. Other pigments may be present in the protoplasm such as in the colored petals of the flowers. Many cells have stored food in the protoplasm. Some of the single celled organisms have special organelles to correspond with the organs of the many called organisms which will be examined later.

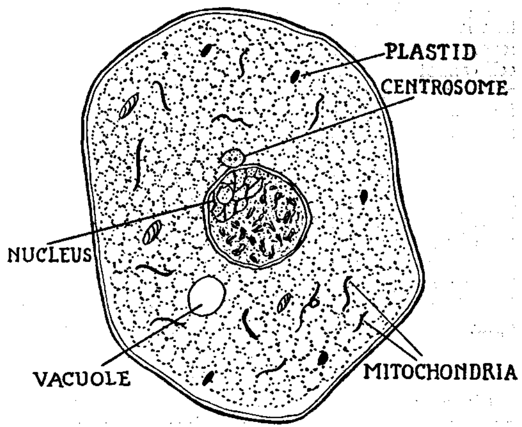


FIG. 10

EXPERIMENT 54. Oil Stored in Cells

Examine a section of orange peel for stored oil drops in the cells. Test also the flesh of a ripe olive.

EXPERIMENT 55. Staining Cells

Stain the different cells that you have looked at with thionine and see how much more detail you can make out in the protoplasm.

EXPERIMENT 56. Cells from Lean Meat

Tease some lean meat, and after you have examined this kind of animal cell stain it with thionine to show the nuclei. Note the cross striations of the muscle cell.

EXPERIMENT 57. The Fibers in a Nerve

Obtain a piece of a nerve from the butcher and tease the end of it to show that it is made of many fine fibers something like a telephone cable. Stain with thionine. You will not be able to see the nucleus of the cells because they are found in the brain or spinal cord and the nerve trunk is composed of the connecting parts of the nerve cells which go to the muscles.

EXPERIMENT 58. Plant and Animal Cells

Examine other kinds of animal cells both unstained and stained and compare your observations of plant and animal cells.

CHAPTER 11
Unicellular Plants and Animals

NAMES. A great many organisms do not have common names and we are forced to use their scientific names. When we remember that there are well over a million and a half organisms it is not surprising that a good many of the names are long and unusual. Most scientific names are Latin because that language is no longer spoken by any nation and its use therefore avoids any patriotic claims of ownership by a nation. Common names vary with different localities, while the scientific names are passed on by an international committee and belong to only one species of animal. The Indian word for clam is quahaug (quo' hog) and the common clam in a region is often called a quahaug. If you ask for some quahaugs in New England, in the Mississippi Valley or on the Northern Pacific Coast of this country you will be given a different kind of clam in each place. That is why in a manual that is to be used in different states we must use the scientific rather than the common names.

In naming a plant or an animal the discoverer is privileged to give it a name and if no other organism has that name it stands; but if another organism already has the name then the international committee and the discoverer have to give it another name.

The scientist puts the name of the kind of animal or plant first and the specific name last, which is the opposite of the method humans use. We put the given or individual name first and the family name second. Instead of capitalizing all of the names the scientist writes the first name with a capital but not the second. *Homo sapiens* is the scientific name for man and in books the names are usually put into slanted italic letters and in our note books we draw a line under them so that the names are clearly indicated.

There are so many plants and animals that no biologist can know all of them. For our purposes we can recognize a number from our previous knowledge or from the pictures in the manual. If you wish to learn more organisms you may read the books on classification in the appendix of the manual.

In the last chapter the cell was shown to be the fundamental unit of life. Some organisms are composed of only one cell and others are made up of many cells. First we will look at some of the plants and animals made of only one cell. If it is not winter, we will go to the nearest pond and fill a clean jar with a little mud from the surface of the bottom of the pond, some of the decaying leaves, and other material in the pond, a small amount of living green plants and the rest water. Let this set in a north window or where it will not be exposed to bright sun and let it settle until the water becomes clear.

After it clears and you look into it you may see some tiny organisms swimming about in it but these are so small that you can barely see them. Catch a few of these in a little of the water with a medicine dropper and put them on a clean slide and gently lower a clean cover glass onto the drop. Do not push the cover glass down or you will crush and kill all of the organisms. If you study the slide for some time you must add a drop of water to the edge of it to replace that lost by evaporation. If this is not done the animals will be killed. Be sure that the medicine dropper, slides and cover glasses are washed clean, as any chemicals left on them will kill the tiny plants and animals.

You may ask what shall I do if it is winter and there are no unfrozen ponds? Then you make a hay infusion. Boil enough water to nearly fill a pint glass jar and when it is cool put it into the clean glass jar and then put into this a small amount of hay. Let it set in a warm room for a few days and you will soon see tiny objects swimming

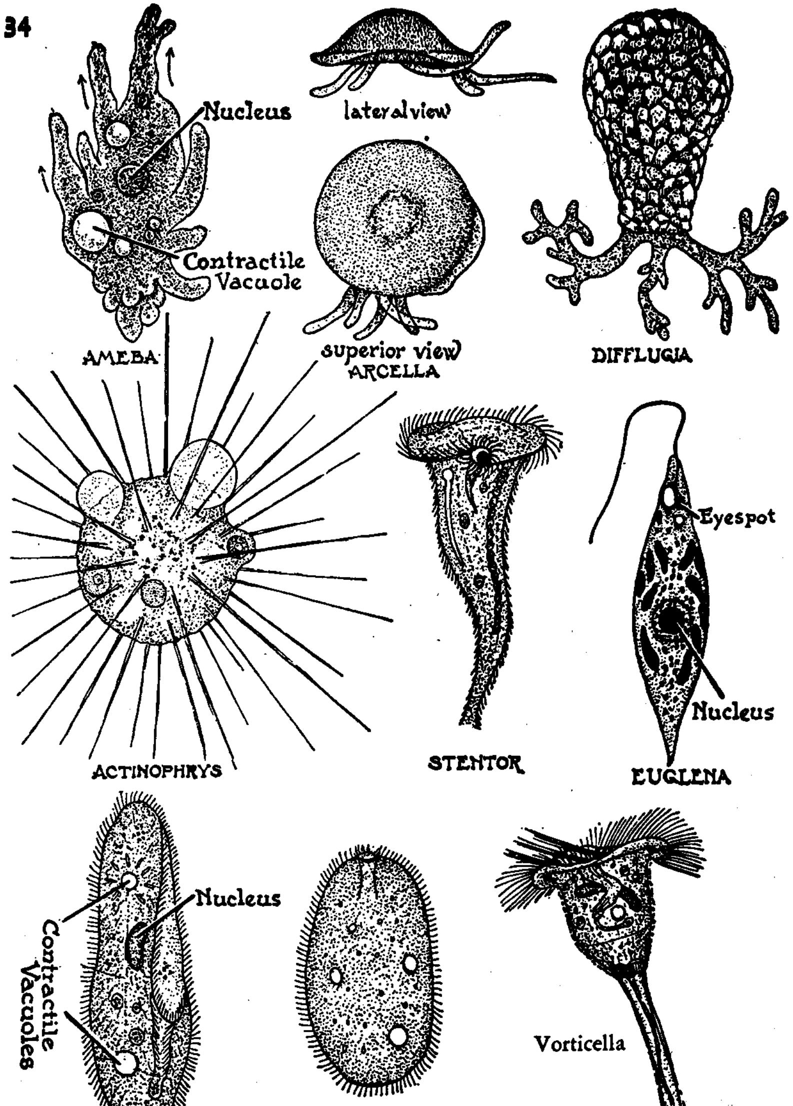


FIG. 11
Courtesy General Biological Supply House

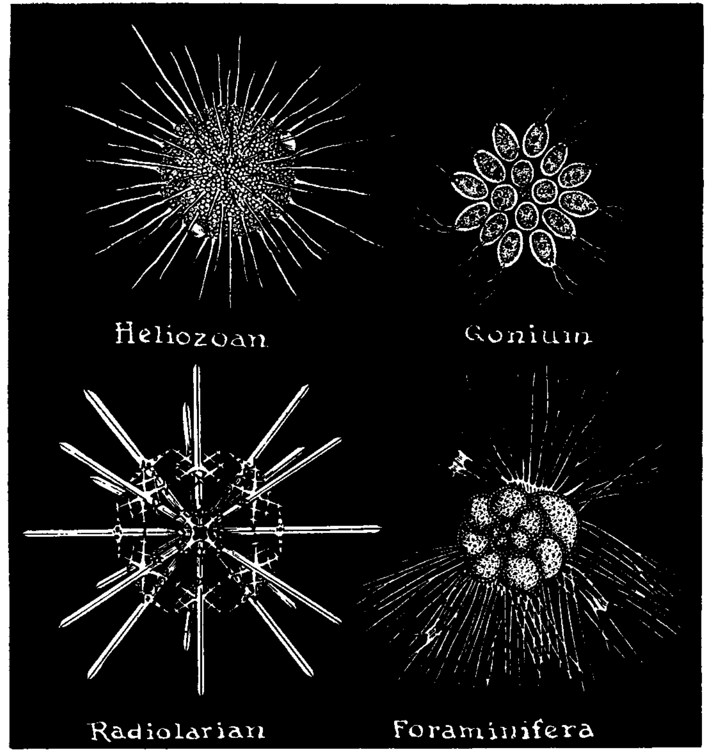


FIG. 11 *Courtesy General Biological Supply House.*

about in it and then you may examine them as described in the last paragraph. In place of the hay you may use a little lettuce leaf or a few wheat kernels. The tiny organisms were present on the hay or grain in a resting form and just needed the water to start living an active life again. You may wish to make several cultures in this manner. One can have subjects to look at with very little trouble anywhere and at any time of the year.

The most common animal in such cultures is apt to be *Paramecium,* fig. 11. It is large for a single celled animal being easily seen as a tiny speck with the naked eye. Under the microscope you will see that one end is pointed and that there is a groove along one side which opens into a mouth. Near either end are the contractile vacuoles which close, or disappear every few minutes, and force the waste materials which collect in them out into the water. The animals swim quite fast and you may have trouble moving the slide to keep them in view. Take off the cover glass and put a small bit of lens paper onto the drop containing the animals and replace the cover glass. Some of the animals will get into small spaces among the fibers of the paper and when thus trapped are easily watched. Another method for quieting them is to use a little thick gelatin solution which slows up their movement.

EXPERIMENT 59. The Paramecium

Find a *Paramecium* and notice whether or not it can swim equally well in both directions. Notice the contractile vacuoles. Can you see bits of food passed along the groove into its gullet?

EXPERIMENT 60. Defences of a Paramecium

Run a little thionine under the cover glass and as it reaches the animal you will see these spears which are called trichocysts (trick' o sists) extend out from the animal. As they are several times longer than the cilia you can easily distinguish them from the cilia.

Another interesting organism is *Euglena,* fig. 11. If you adjust the light until it is just right you will see that this animal swims by a single, whip-like lash called a flagellum (fla gel' um). It is able to contract its body so that it appears to squirm about. This organism contains green bodies of chlorophyll and can make its own food in the light like a plant, but in the dark it can live like an animal. It represents one of the simplest kinds of life and it is not possible to decide whether it is a plant or an animal.

EXPERIMENT 61. The Euglena

Find an *Euglena.* Can you see a little red spot near the base of the flagellum? It is sensitive to light and resembles an eye.

EXPERIMENT 62. Comparison of the Euglena with the Paramecium

Stain an *Euglena* with thionine and compare its nucleus and other parts with that of the *Paramecium.*

One of the most interesting smaller animals is *Amoeba,* fig. 11. This animal is harder to find as it tends to hide among bits of dirt at the bottom of the dish or in decaying bits of leaves or other vegetable matter on which it feeds. It keeps changing its shape by pushing out foot like processes or pulling them in. It may become nearly round at times. It has a single contractile vacuole and when stained shows the large round nucleus.

EXPERIMENT 63. The Amoeba

Find an *Amoeba* and make a record of its change in shape by making an outline sketch of it in your notebook every two minutes. Can you see it roll around some food with one of the foot-like processes? Stain the *Amoeba* with thionine to see its structure.

Chalk comes from the gradual accumulation of the skeletons of small one celled animals called Foraminifera (For' am i nif' er a) at the bottom of the sea. Then as the level of the bottom of the sea raised, the beds of compacted chalk appeared and man could mine the chalk for use.

EXPERIMENT 64. What Chalk Is Made Of

Scrape off a bit of chalk into some water and examine it under the microscope for skeletons of animals like the Foraminifera, fig. 11. Artificial chalk is made by grinding up calcium carbonate and pressing it together, so if you do not find any animal skeletons you know that your sample of chalk was made artificially.

EXPERIMENT 65. Foraminifera

If you find *Foraminifera* place some fine scrapings on a slide under a cover glass and add a little vinegar to the edge of the cover glass. As it runs in it will dissolve the calcium carbonate of the skeletons and give off carbon dioxide gas.

These animals are of commercial importance because their skeletons are also found in the ground. Some of them are found with oil deposits and now the microscopist studies the dirt brought up when new wells are drilled and he can frequently tell from the skeletons of these animals whether or not oil is apt to be found in large quantities.

Fuller's earth or diatomaceous earth (di a to ma' ce us) is used as a polishing medium and to absorb color in purifying liquids. It is composed of skeletons of *Diatoms,* fig. 12. These are plants and when they are living contain green chlorophyl in their protoplasm. The shell is made of two parts which fit together like a pill box. Some are round, others oval or oblong, boat shaped etc. The skeleton is marked with fine lines or pits and some of the markings are so fine that they are used to test the resolving power of the best microscope lenses.

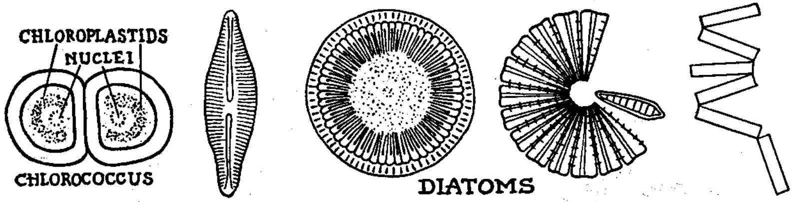


FIG. 12. *Courtesy General Biological Supply House.*

EXPERIMENT 66. Diatoms

Take a little of the diatomaceous earth that comes with your set and mount it in water and examine with your microscope.

EXPERIMENT 67. Diatom Skeletons

Test a little diatomaceous earth with acetic acid as you did in exp. 65. The Diatom skeletons do not dissolve in the acid because they are made of silica like glass. This is another method, besides their appearance, of telling them from the *Foraminifera.*

EXPERIMENT 68. Testing Silver Polish

Rub up a very small amount of your mother's silver polish in a little water and mount under a cover glass and look for diatoms in the polish.

Because these glassy skeletons are hard they are used as an abrasive in polishing materials. They are some times used in poor grades of tooth paste but they should not

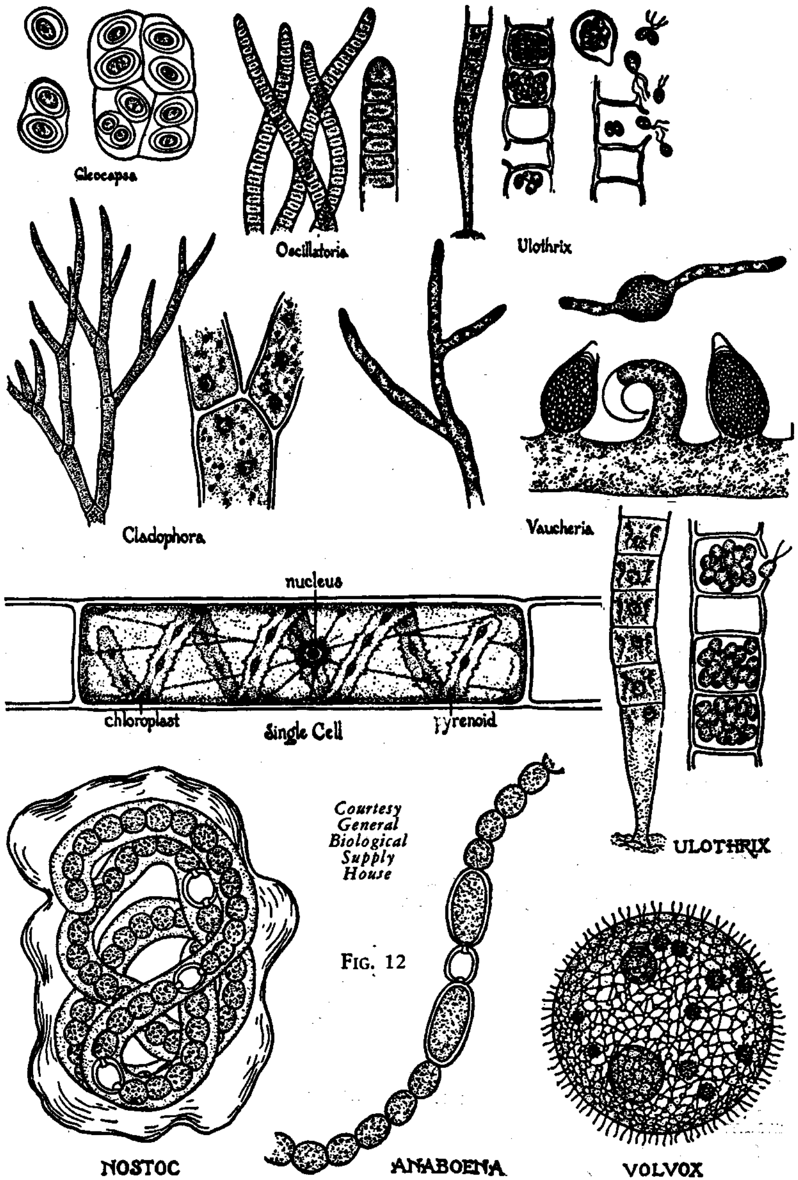


FIG. 12

Courtesy General Biological Supply House.

be used for this purpose because they are so hard that they will injure the enamel on the outside of the teeth.

EXPERIMENT 69. Testing Tooth Paste Abrasive

Examine a bit of your tooth paste to make certain that it does not have diatoms in it.

EXPERIMENT 70. Living Diatoms

Look for living diatoms in your cultures from the hay or from the ponds.

When you see some green scum on the surface of a pond be sure to mount a tiny bit of it and look at it with your microscope.

EXPERIMENT 71. Spirogyra

If it feels slippery to your fingers you will probably find that the filament is made of cells and its *Spirogyra,* fig. 12. The chlorplastid which contains the green coloring matter is wound around the central sap space in the form of a spiral.

EXPERIMENT 72. Volvox

If you find some *Volvox,* fig. 12, it makes a most interesting object for study. The green round masses may just be seen by the unaided eye, but under the microscope they show a great many green cells held together by a colorless cementing substance. Inside the colony are formed other smaller colonies.

You will see the other plants and animals shown in fig. 11 and 12 and a great many others as well. There are so many of these organisms that some people make the study of them their hobby. They are of great importance to all of us because if certain kinds of them get into our water supplies they may cause it to taste bad. The chemist of the Public Health Department has to examine the water at frequent intervals and if too many of the wrong kind appear proper treatment is necessary.

EXPERIMENT 73. Yeast Cells from a Yeast Cake

Take a very tiny piece of a compressed yeast cake, about the size of a period, and rub it into a drop of water, mount under a cover glass and examine with the microscope. The cells are small, about 7-9 micra in diameter, but much larger than bacteria.

EXPERIMENT 74. Starch in a Compressed Yeast Cake

Add a drop of iodine to the preparation. The starch granules stain blue while the yeast remain colorless or stain slightly brown. The starch was added to keep the cake moist. Can you tell the kind of starch used?

EXPERIMENT 75. Growing Yeast Plants

Make a slide with a little sugar solution instead of water. Place bits of cover glass at the corners to support the cover glass and seal the edges of the cover glass to prevent the water from evaporating. Watch a bud form and grow up to a mature cell. Use from ten to fifteen times as much water as sugar and very little yeast for best results.

Mold grows on many objects which are left in damp places and the mold plants make interesting subjects for our microscopes. It is easy to obtain the common bread mold by dampening a piece of bread and leaving it exposed to the air. The spores fall on it and grow. When the mold does not appear in a day or so, sprinkle a little dust on the bread. Dust almost always contains mold spores. At first a fine filamentous growth appears on the bread, then some of the filaments grow upward, the ends round and turn dark colored as the spores form in the clubshaped ends.

EXPERIMENT 76. Bread Mould

Pick off a little bread mold with your forceps and examine it in a water mount. The spore bearing heads grow up together and the filaments join one another like those of fig. 13A. A spore finds a suitable place and grows up into a colony. All the protoplasm from this spore is connected without separate cell walls and the many nuclei are scattered throughout the protoplasm, fig. 13D.

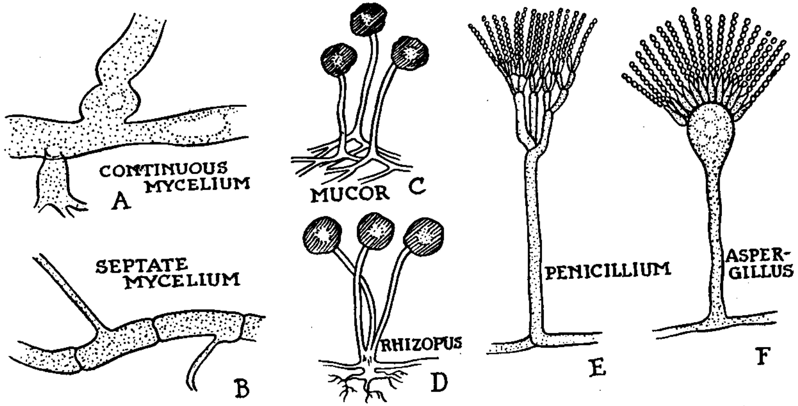


FIG. 13

The different kinds of molds are distinguished according to whether the filaments are continuous, fig. 13A, or divided as in fig. 13B, also whether the spores form in a club shaped end like the bread mold, fig. 13D or form in chains like those of fig. 13E & F.

EXPERIMENT 77. Mucor

Look for another common mold Mucor, fig. 13C.

EXPERIMENT 78. Molds of Fruit and Jelly

Examine some moldy fruit and jelly for molds with spores in the form of chains, fig. 13E & F. These molds are often bright colored because the spores may be green, orange or brown.

Cells increase their numbers by dividing into two cells, by forming buds, or by forming many spores. When a cell grows large it pinches itself into two either crosswise or lengthwise. Watch for cells in the process of dividing as you examine different preparations.

With the exception of the molds, the cells mentioned in this chapter are considered single celled organisms because the cell is the living unit even though it may be duplicated and the resulting cells form chains or filaments. You may easily find a great many other interesting one celled plants living near you.

CHAPTER 12
The Many-Celled Animals

All of the processes of life such as eating, reproducing, moving, etc., have to be done by a single cell in the single celled organisms that we examined in Chapter 11. The larger number of animals are built up of a great many cells of different kinds. They are larger and only the smaller ones can be studied with the microscope. The different tissues must be prepared and studied separately from the ones too large to go on the microscope. The biologists divide these animals into some fifteen main groups and we can only look at a few of them now, but you can use the same methods with other animals and extend your information almost without limit during your life time. If you would like to read more about the animals there are books listed on Zoology in the appendix which may be borrowed from your library or bought at a book store.

You have seen some of the smaller many celled animals when you looked at your collection from a pond. After your collection has settled for a while you may see *Hydra* attached to a bit of plant or to the side of the container, fig. 14. When it is expanded it may be from 1/8" to 3/8" long. If it is disturbed it contracts into a small round ball. The mouth is on the raised part between the arms. The arms have stinging cells on them.

EXPERIMENT 79. Hydra

Watch a Hydra in a small clean dish and then gently place it on a slide and cover with a cover glass. You will see that the body is made of two layers of cells. Run a little thionine under the cover slip and it will stain the animal and will also cause the stinging cells to discharge their fine lances.

You have probably seen round worms wiggling on some of your slides like those in fig. 14.

EXPERIMENT 80. A Round Worm

Examine a round worm closely. Its digestive system may be seen through the body wall.

EXPERIMENT 81. A Flat Worm

Watch a flat worm, fig. 14 to see how it moves. The surface of it is covered with cilia similar to those you saw on *Paramecium*.

Flatworms like *Planaria* can grow new parts in case they have an accident and this ability is called *regeneration*.

EXPERIMENT 82. Regeneration of an Injured Worm

Cut a flat worm in half with a razor blade and put each half into clean pond water in clean dishes and watch the parts for a few days. They will usually regenerate the lost parts and change back to the same form as they were originally but each will be smaller. Does it make any difference whether you cut the worm in two crosswise or lengthwise?

There are many small crustaceans in pond water which have hard shells, and paired, jointed legs. Some of them are so small that you can see how their internal organs work as you look at them under the microscope.

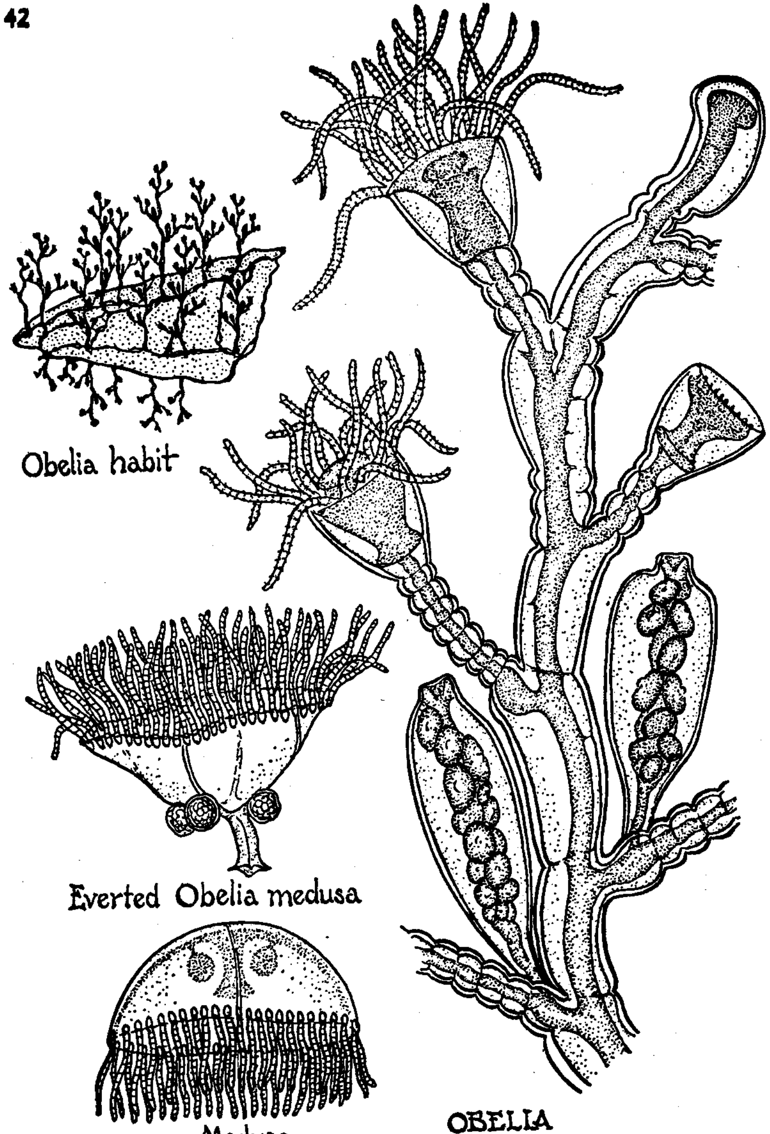


Fig. 14

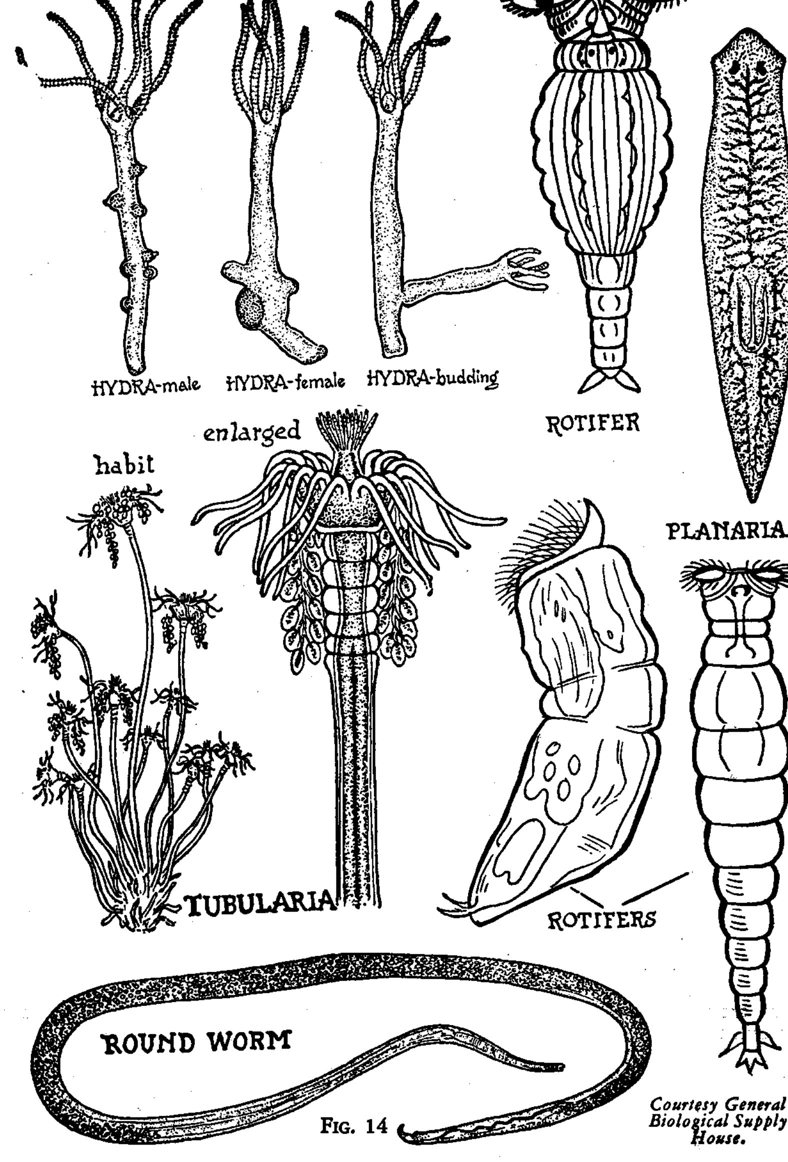


Fig. 14

Courtesy General Biological Supply House.

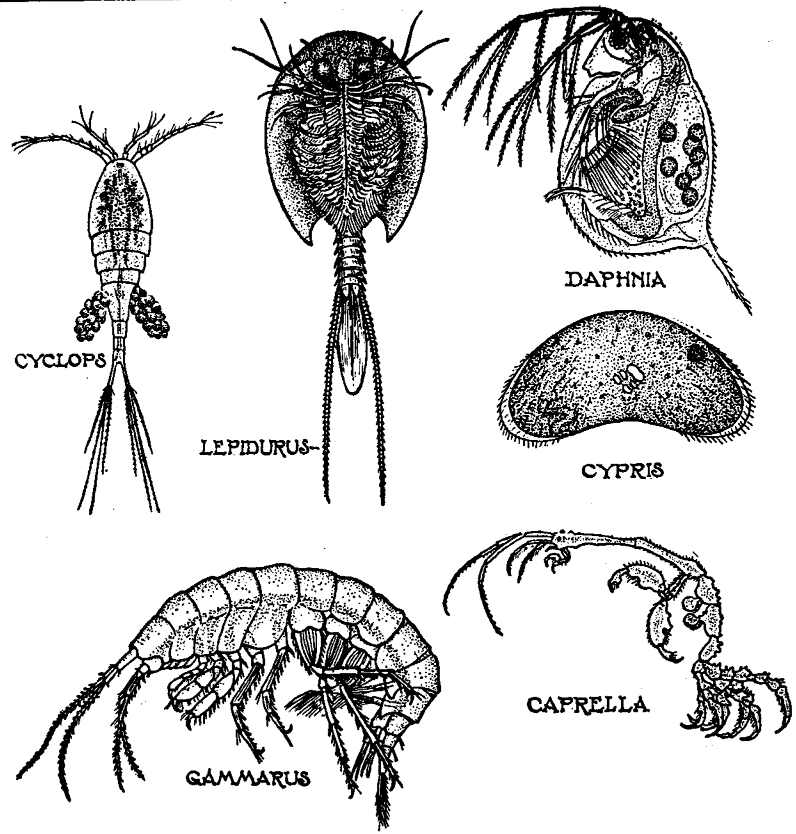


Fig. 14
Courtesy General Biological Supply House.

EXPERIMENT 83. Crustaceans

Look for some small crustacea like *Cyclops, Gammarus, Daphnia* and see how they move. Fig. 14.

When you are at the seashore look at the seaweed and if you see some fine hair like growths on the seaweed put a little on a slide with a drop of *sea water* and examine them.

EXPERIMENT 84. Sea Moss

Two of the most interesting ones are *Obelia* and *Tubularia,* fig. 14. In *Obelia* the branches end in two kinds of heads. One kind look like *Hydras* and catch the food

for the whole animal. The other kind grow small jelly fish on the central club shaped part. If you have them during the summer you may see some of the small jelly fish, called medusae (me duse' e) break off and swim out the opening in the protective covering. The medusae have sex organs and the fertilized egg from them grows up into the animal with the different parts connected by a common stem.

Rotifers, fig. 14, are sometimes called wheel animalcules because they have a row of cilia around the head end. They are very common and usually found in samples of pond water like you obtained in Chapter 11.

EXPERIMENT 85. Wheel Animalcules

Examine some different kind of Rotifers.

The larger animals can be seen under the microscope part at a time. The insects are very interesting and so that you may study it at any time you wish a fly is included in your set.

EXPERIMENT 86. The House Fly

Take the fly and see how many parts it has with the aid of your hand lens. Then look at the different parts with the microscope. To do this pull the part off with the forceps and place it on a slide in some water under a cover glass. If you wish to make the preparations last longer use glycerine instead of water. Insect parts may be dried in the air, gently warmed and mounted in balsam for permanent preparations. Examine the legs and note the swelling or pad at the end. This secreted a sticky material when the fly was alive so that it could stick to the window pane and walk straight up. Examine the compound eye which is made up of a great many separate eyes all bound together, the wings, the antennae on the head and the mouth parts.

EXPERIMENT 87. Mosquito

Catch a mosquito and see how its mouth is made for sucking blood from the victim that it bites.

EXPERIMENT 88. Fruit Fly

Catch a fruit fly and compare its parts with the larger house fly.

EXPERIMENT 89. The Cause of the Cricket's Chirp

Catch a cricket and examine its legs. You may find a rough edge which has fine saw-like teeth on it. It makes its chirp by rubbing these parts together. Other insects make their noises by rubbing similar rough strips together on the edges of their wings.

EXPERIMENT 90. The Honey Bee

The bee makes one of the most interesting insects because so many of its parts are made into special tools, fig. 15. The bee has a compound eye on each side and three simple eyes on the head above and between the compound eyes. Note how the mouth parts make a sucking tube for drawing the sweet nectar from the flowers into the mouth. Notice the heavy jaws. The sting is at the other end and may be removed by taking hold of the tip of the abdomen with the forceps and gently pulling. The stinging apparatus is composed of two barbs, the poison sac and the muscles for driving the barbs into the victim. When a bee stings, the stinging apparatus is

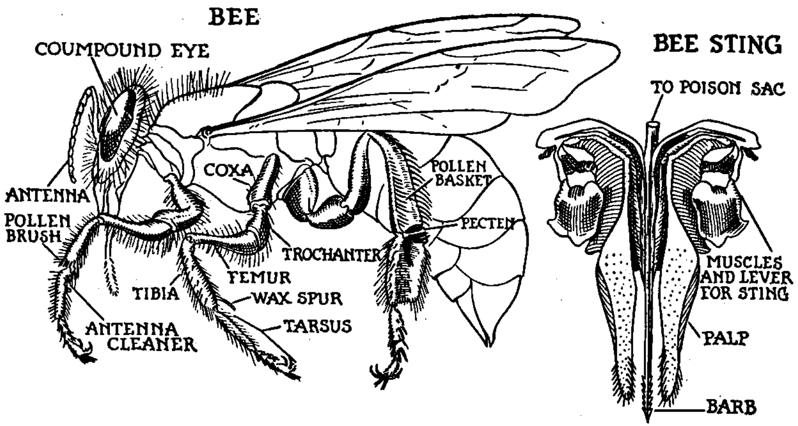


FIG. 15

usually pulled out from the bee and the muscles go on driving it into the skin. So if you happen to be stung by a bee pull the sting out as soon as you can so only a little of the poison will be injected from the poison sac into you.

The legs are each composed of five parts as labeled in fig. 15. On the front leg notice the pollen brush and the antenna cleaner. The feeler or antenna is pulled through this to clean it. Notice the pollen spur on the middle leg which is used as a pry bar in handling the pollen collected in the pollen basket which you will see on the hind leg. On the hind leg is a row of stiff hairs which serves the bee as a brush. The bee has many tools built into its body. Can you find more of them?

EXPERIMENT 91. Insect Wings

Compare the markings on the wings of different kinds of insects. Insects are arranged into groups according to their wing structures.

EXPERIMENT 92. Scales of a Butterfly's Wings

When you catch a butterfly mount a bit of the wing on a slide and see how the scales are arranged on the wing like shingles on a roof. Are the scales the same shape on different kinds of butterflies and moths?

A clam or fresh water mussel contains many interesting tissues.

EXPERIMENT 93. Ciliated Cells from a Clam

Break the shell so that you can see the living animal inside. There is a fold of tough membrane on each side just inside the shell. Inside this membrane are the gills—two pair on either side. Take a little of the gill material out with the forceps and tease it out so you can see the cells of which it is made. On the edges of these cells you will see cilia like you did on *Paramecium.* The cilia cause the water to flow over the gills so that the clam can breathe. Staining the cells will show the cilia better but will kill them so that they will no longer move. You can study the tissues of many kinds of animals by teasing them with the dissecting needles in a similar manner.

Fish scales are very interesting and those from each kind of fish are different, fig. 16. A few scales are furnished with your microscope set. You may get others from fish you catch or from a fish market. Those from a fresh fish will have to be cleaned with water and a good rubbing and may be looked at dry or in water mounts. Try staining some. When they are thoroughly dry they may be made more transparent by soaking for a few minutes in xylene and then mounting in balsam as permanent mounts. More detail may be seen in the mounted scales.

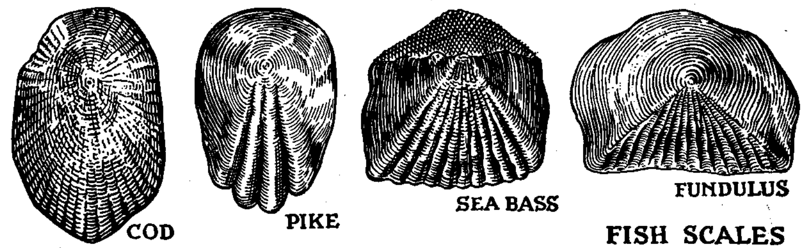


FIG. 16

EXPERIMENT 94. Fish Scales

Look at the scales that come with your set and at other scales and make sketches in your note book so you will be able to name the fish from a scale you may pick up later.

The animals which contain back bones are grouped according to their skin structures. The scale characterizes the fish. The Amphibia, frogs, toads and salamanders have moist skins with no scales. The Reptiles have dry skins with scales which are quite different from those of the fish as you will see if you have a chance to examine a snake or a lizard. The alligator and the turtle have bones in the skin for protection and the bones in the turtle join to make its shell. The feather defines the birds and should be examined by the microscopist. The mammals have hair as described in Chapters 6 and 16.

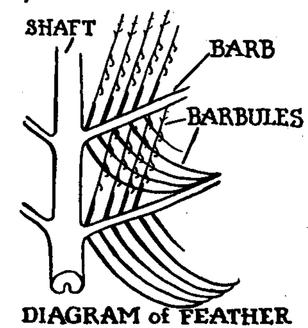


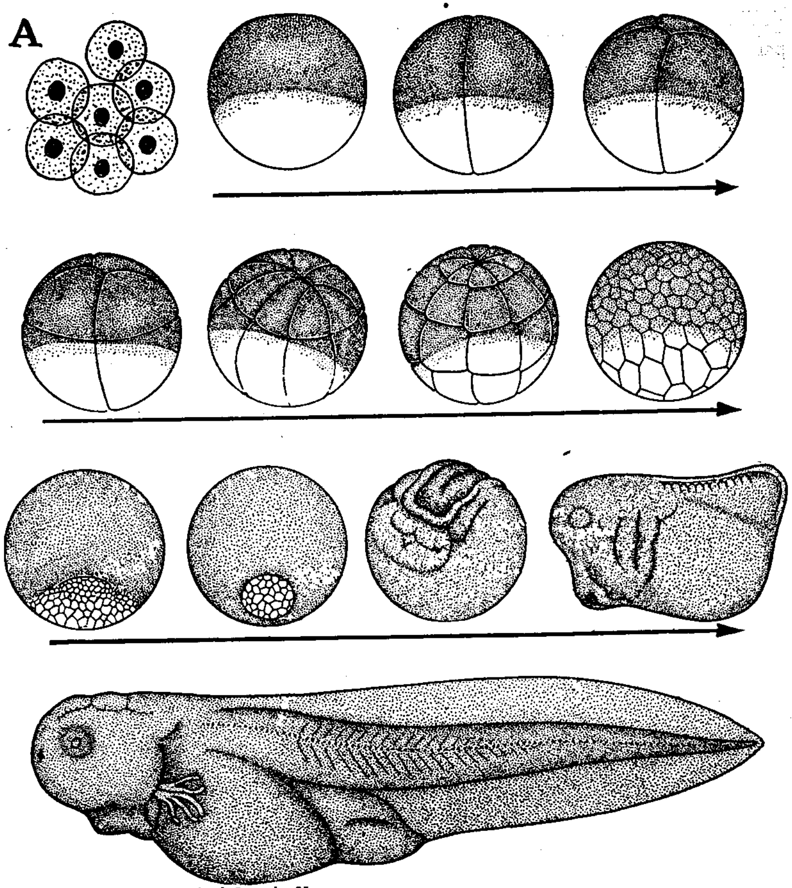
FIG. 17

The small down feather is made of a central shaft and small branches as you see in the feather slide that comes with your set. A larger feather has side branches from the center shaft and further branches from these which hook into those of the next one as shown in fig. 17. It is this locking which gives stiffness to the feather and if the feather parts are separated it is not possible to put them back unless you do it under a microscope.

EXPERIMENT 95. Why Feathers Are Stiff

Note the hooking arrangement of the finer branches of a feather.

Some morning in the spring go out early and look for frog or salamander eggs layed in small ponds. They are usually in masses looking like small dark spots in a jelly case, fig. 18. When you carefully pull the jelly off with your forceps and dissecting needles and look at the egg in a small glass dish you will see that the upper part is dark and that the lower part is light colored due to the yolk food material.



Courtesy General Biological Supply House

FIG. 18

A. Frog eggs. B. Frog eggs magnified. Reading to right shows early stages of development.

Some of the eggs may be divided by a groove into two parts. Later another groove may be seen going around the egg at right angles to the first to divide it into four parts. The third groove divides the four into eight, etc., fig. 18. After a time the cells are so small that they cannot be seen as separate cells and you will see that the

dark cells gradually cover the lighter colored ones until finally only one spot of light ones may be seen. About this time a groove bounded by folds forms and at the end away from where the last light cells are seen, the head will gradually form. To see this the egg must be kept covered in water in a glass dish small enough to go under the microscope and you will use the low power of your microscope.

This process of the egg developing into the tadpole is fascinating and should be seen. The study of the development of animals is called embryology (em' bry ol" o gy). Other eggs may be studied in a similar manner.

EXPERIMENT 96. The Development of a Frog Egg

Collect some frog eggs and watch them develop. Keep a record of how long it takes for each stage. Unless you get the eggs early in the morning they will have developed beyond the first stages and you can only see the later stages. The frogs lay the eggs in the very early morning. The rate of development depends on the temperature; they develop faster on warm days or in a warm room.

CHAPTER 13
Printing.

Printing depends on the nature of the raised type used to carry the ink and the nature of the surface on which the ink is pressed in the printing press. The microscope is used to examine the impression and to determine what kinds of paper are suited to different reproduction purposes. With real engraving the space for the ink is cut into a metal plate, the plate is inked and all of the ink on the surface of the plate is rubbed off and then the plate is pressed against the card or paper so that the remaining ink sticks to the paper and is left as a raised letter. With imitation engraving ordinary type is used with a special ink which is heated after printing so that it swells to resemble engraving. With real engraving the letters will show some variation because they are cut by hand, while the letters of artificial engraving are uniform.

EXPERIMENT 97. Engraving

Examine some engraved calling cards, party or wedding invitations with the hand lens and the low power of the microscope to see whether they are real hand engraved or made by the imitation process.

Simple illustrations are usually made as line cuts by a combined photographic and chemical process and the cut printed along with the reading matter.

EXPERIMENT 98. A Line Cut Impression

Look at a printed line picture and notice whether the lines are continuous or whether they are made of dots. If the lines are continuous and not made of dots it was printed from a line cut.

To print pictures with intermediate shades of gray rather than just black and white the pictures must be photographed through a screen of diagonally crossed lines when the plate is made. This breaks the picture up into masses of dots and when this kind of plate or halftone, is printed the result is a lot of dots. Light gray has fine dots and black comes out as large dots. Every intermediate stage is possible. Halftone plates for printing on rough newspaper have coarse dots because they were made with a coarse screen while pictures printed on very good paper have fine dots produced by very fine screens.

EXPERIMENT 99. A Coarse Screen Halftone Picture

Examine a picture in a newspaper with the hand lens and low power of the microscope to see how the dots are arranged and their size. To see clearly on the microscope cut out a piece small enough to put on a slide and place another slide on top to hold it flat. If it is too opaque rub a little oil, or xylene, on the paper back of the part examined to make it pass more light.

EXPERIMENT 100. A Fine Screen Picture

Examine a picture from one of the better magazines printed on good paper and compare with the newspaper picture. The microscope shows why you can see more detail in the better picture.

Many colored pictures are printed from different plates so arranged that each prints exactly on the other. Usually the three colors red, blue and yellow are used. A part having one of these colors will show just the fine dots or a smooth mase of this color while a part of another color like green will be printed from the yellow and the blue plate and will show both colors under the microscope, but because the dots are too small to see with the naked eye we see the blend, or green.

EXPERIMENT 101. Printed Color Plate

Examine a colored picture from one of the better magazines to see how it was printed. Do the dots form a microscopic pattern?

The rotogravure sections of the Sunday newspapers are printed with a special ink which runs enough to fill in the spaces between the dots and gives a smoother picture.

EXPERIMENT 102. Rotogravure Pictures

Compare a picture printed in rotogravure with a picture printed from a halftone plate with your hand magnifier and your microscope.

The colored "funny paper" or comic strip is printed partly as smooth color and partly as dots which is known as the Benday process. Sometimes the blue and yellow are printed as smooth color and the red as dots. A purple would be made from the smooth blue and over printed with red dots.

EXPERIMENT 103. A Benday Picture

How are the colors printed on a colored comic strip for your Sunday newspaper?

CHAPTER 14

The Structure of the Photographic Image

The film that you place in your camera has a light sensitive emulsion of silver salts placed on a celluloid support. When you take a picture the lens focuses an image of whatever the camera is pointed at onto the film and the light changes the silver salts in accordance with the amount of light received on each part of the film. The film is developed with chemicals which change the silver salts affected by the light into metallic silver and which wash out the silver salts not affected by light. The resulting negative contains dark regions with lots of tiny silver masses in the regions which were light in the original and the shadows are registered on the negative by much lighter deposits of silver because less light was reflected from them to the film.

EXPERIMENT 104. Structure of a Photographic Negative

Look at a photographic negative with the low power of your microscope and then with a higher power until you can see that the metallic silver deposits are made up of individual grains.

Some developers like pyro produce a stain in addition to the silver grains.

For printing the negative directly onto paper by contact the fineness of the grains does not matter very much, but if the negative is to be enlarged many times the grains in the negative must be so small that they will not be seen separately by the eye after the negative is enlarged.

EXPERIMENT 105. Limitations of Enlargement

By looking at a negative you can decide how much it may be enlarged and still look well. Look at some different negatives and see whether they could be enlarged 3, 5 or 10 times without the grain becoming objectionable.

EXPERIMENT 106. Correspondence in Grain Between Negative and Enlarged Print

Compare the appearance of the negative and of an enlargement from it with your lenses.

For great enlargement of a picture the negative must have very fine grained particles of silver and special fine grain devolpers are prepared for this purpose. The fineness of the grain in negatives from the modern miniature cameras must be preserved and with proper processing the prints from enlarged negatives five or more times may be as good as contact prints made from larger negatives.

EXPERIMENT 107. Fine Grain Developer

Compare the grain size of negatives developed in fine grain and ordinary developers.

If you do your own developing and printing you will find that the microscope will help you to make better pictures because you can see just how they are formed. You will think of many other experiments such as the effect of the temperature of the solutions on the grain size, and you can compare the results of different kinds of developers and films. You may look at the paper prints as well as the negatives.

A drop of xylene on the back of the print will make it transparent enough for you to use the low power of the microscope with a strong light. The picture will not be harmed by the xylene which quickly evaporates.

Reversal film used in the 8 and 16 mm. motion picture cameras often has finer grain than ordinary camera film. Of course any picture will have small and large grains of silver in it so we have to make our comparisons of the average size of the grains of the pictures.

EXPERIMENT 108. Reversal Film

Do you find the average size of the silver grains different in a still camera negative from those in reversal film?

Pictures taken in natural color are produced in many different ways and it would take a large book to tell you all about them and how they work. The usual method is to separate the colors of the pictures into three primary colors red, blue and yellow by proper filters and then to combine the colors by complimentary dyeing of the images on the film or films. If you have any of these pictures look at them with your microscope to see how they are made.

The Autochrome plates have a filter of colored starch grains between the emulsion and the glass which you can see by looking through the back of the film with your microscope. Other processes have filters of colored oil droplets in the emulsion. The Agfa color plate has a color screen of particles and the Dufay screen is ruled on the celluloid by diagonally crossed colored lines. The Finley plate has no color screen built into it but you place such a screen in front of the plate when taking the picture and a different screen called a viewing screen in front of the finished picture when you look at it. The Kodachrome film has three color images in different layers obtained by toning the original images when the film is processed.

EXPERIMENT 109. Natural Color Films

Look at as many kinds of color films as you can get and see how the image of each is produced. Small bits of the film permanently mounted in balsam make interesting slides to show your friends. A friend of yours in a photographic store may be able to give you some small bits to mount and look at. You will find silver images in some of the color processes as well as the colored images.

CHAPTER 15

Metallurgy and the Microscope

The surfaces of different kinds of metals show quite different kinds of structure and grain, which is important as an index of rusting and wearing ability. A rough surface would not be a good metal for a bearing so a smooth surface metal mixture like Babbit metal must be used instead. The same metal finished in different ways appears differently under the microscope. Many metals used in industry are not pure but are alloys or mixtures of several pure metals and in some cases the microscopist can tell about what proportions of each were used in the mixture. The following experiments will be interesting and may suggest others. The microscope is very important when flaws in broken surfaces must be studied.

EXPERIMENT 110. Rusty Iron

Take a bit of rusty iron and polish off part of it so you can compare the surface of the metal with the part covered with the iron oxide rust.

EXPERIMENT 111. Metal Surfaces

Compare the surface markings of copper, silver, and other metals. Coins may be used.

EXPERIMENT 112. Metal Plated Surfaces

Examine different surfaces such as chromium plating, nickel plating, cadmium plating, etc., with your microscope.

EXPERIMENT 113. Flaws in a Broken Surface

Examine the broken surface of the next bit of broken metal you find to see whether it was a clean break or whether there was a flaw in the metal which weakened it so that it broke at the place.

Brass is an alloy of copper and zinc, although a little tin is sometimes added. It is one of the more interesting metals for examination with the microscope.

EXPERIMENT 114. Alloys and Its Components

Compare tin, zinc and copper with brass. Are all brass objects made of the same kind of brass? What happens to the surface of brass when it becomes dark and when you polish it. You will find tin as a plating over iron on tin cans and boxes, the outside of dry batteries, such as are used in flashlights, are made of zinc. Copper can be found on the top of the center of the battery or you may find some copper wire around the place.

CHAPTER 16

Textile Microscopy

The nature of cloth and its ability to be colored with different dyes depends on the kind of fibers from which it is made. Much of our knowledge of the fibers has come from experimenting with them under the microscope. The microscope is necessary in some cases to know from what material a cloth was made and to determine the quality of the goods. The microscope shows us whether the cloth was made with new fibers or whether part of the fibers were reclaimed from some used cloth, it shows whether the fibers are in good condition or whether they have been damaged by molds and mildew or by careless handling in manufacturing. From this knowledge we can tell whether they will wear well and whether they are what they are claimed to be.

One needs only a small bit of thread for a microscopical examination so you can get a sample from garments near a seam without damaging them. It is well to take one piece of thread about ½" long from the warp fibers running one way in the cloth and another from the woof fibers which cross the former ones, because sometimes they are of different material. Put the thread into a drop of water on a slide and tease the fibers apart at one end with a dissecting needle while you are holding the other end with the forceps or the other needle. It may be easier to do this under the hand lens. When the individual fibers that make up the thread are well separated add a cover glass and examine with your microscope.

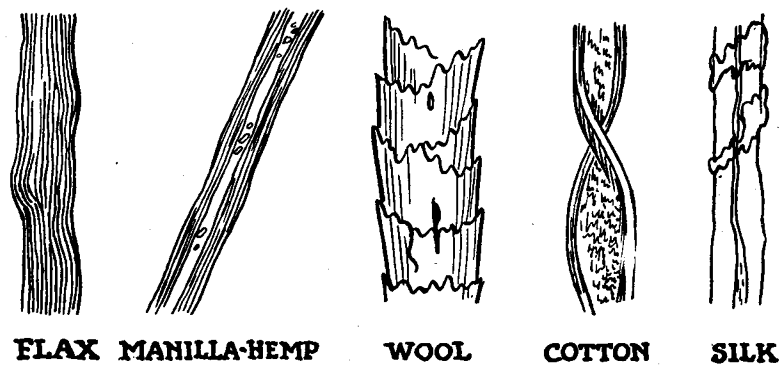


FIG. 19

Wool is the hair from the sheep (Chapter 6) and shows definite scales on its surface, fig. 19. These scales permit the fibers to felt together and give wool its springy feeling. Wool fibers burn slowly and the burning end tends to form a rounded glowing ball. Wool dissolves in moderately strong lye (sodium hydroxide) while cotton does not. When the wool fibers have been dyed a dark color it may be difficult to see the surface markings, but if you have some hydrogen peroxide in your family medicine chest this may bleach the fiber enough to see its structure. Experts can tell from what part of the world the wool comes from the pattern of the fiber.

EXPERIMENT 115. Wool

Examine some wool cloth and compare the fibers with your observations on other animal hairs.

EXPERIMENT 116. Shoddy

Notice in samples of wool whether the fibers seem to be all of the same color or whether there seems to be a mixture of fibers of different colors. Sometimes wool is reclaimed from old cloth and some of this second-hand wool is mixed with fresh wool to make it cheaper woolen cloth. The old fibers usually have mixed colors and this kind of cloth is called shoddy.

There are other hairs from animals related to the sheep which are used to make fabrics. Mohair comes from the Angora goat and is used in making upholstery material and in some heavy, winter, outer clothing.

EXPERIMENT 117. Mohair

Examine a bit of thread from the cloth on a cloth covered chair. The fibers are straighter than those of wool, the scales are smaller and the fibers seem to have a brighter luster than those of wool.

Cotton fibers come from the hairs on the seeds of the cotton plant and are used more in textiles than any other kind of fiber. The fibers are composed of cellulose and they burn quickly with an odor like that of burning leaves rather than the odor of burned hair you noticed with burning wool. The fiber is ribbon shaped and is a flattened or collapsed tube, fig. 19. The fibers are usually more or less twisted.

EXPERIMENT 118. Cotton

Look at cotton fibers from different samples of cotton cloth and thread.

EXPERIMENT 119. Part Wool Cloth

Examine a number of threads from a suit of woolen clothes to see whether or not some cotton was used with it. If you have any lye in the house make a strong solution of it in one of your test tubes and put some wool cloth in it with the forceps. If it is all wool it will completely dissolve, but if any cotton is present it will remain. Wash it with water and look at it under the microscope to make sure that it is cotton. Caution—do not get any of the lye on your skin and be sure you wash all the dishes you use with lots of water because lye burns.

EXPERIMENT 120. Mercerized Cotton

If your mother has some mercerized cotton thread be sure to examine it. It is cotton that has been treated with a lye solution to give it a higher luster. Other methods with chemicals, heat and pressure are used to make cotton look like silk but you can usually tell under the microscope by noting the twisted ribbon like cotton fibers.

Linen is made from a vegetable fiber found in the stems and leaves of the flax plant. The parts are reted by soaking in water until the softer parts break up and then the long fibers are washed free from the other parts of the plant, dried and twisted into thread. The fibers are round and smaller in diameter than those of cotton. At the ends they appear frayed showing that they are made up of finer fibers, fig. 19.

Linen fibers may have swellings or nodes now and then along the fiber and they are straight and not twisted like you saw with cotton fibers.

EXPERIMENT 121. Linen

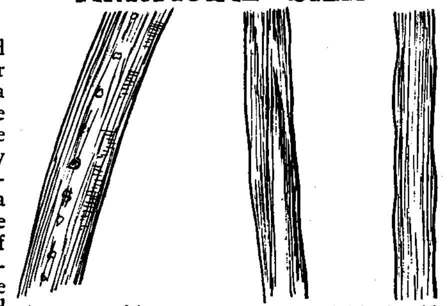
Obtain a small bit of linen thread or some bits from a linen handkerchief and familiarize yourself with linen fibers.

Silk used to be one of the more important kinds of cloth but the modern artificial silks are cheaper and are displacing real silk. The silk fiber is composed of two fine protein fibers cemented side by side as they are secreted from the spinning glands of the silk worm, *Bombyx maori*. The larva eats mulberry leaves and grows until it is ready to spin its cocoon which it does with the silk. Man has learned how to unwind the silk fibers, to clean them, and to twist many fibers into silk thread for making cloth. The natural silk from the cocoon is yellowish and may have masses of the fibroin cement substance on it. This is washed off in hot soapy water. The resulting fiber looks like fig. 19. The fibers are very small and smooth although the size of the fiber may vary a little and sometimes it shows the marks of other fibers which crossed it in the cocoon before it had dried hard. Other insect larvae make cocoons but the silk is not of as good quality as that from the silk worm, the cocoons may contain leaves and other material and cannot easily be unwound.

EXPERIMENT 122. Natural Silk

Untwist some silk thread and observe the individual fibers.

ARTIFICIAL SILK



COLLODION CUPRAMMONIUM VISCOSE

FIG. 20

The artificial silks are often called rayons and because they are cheaper they have replaced natural silk to a large extent. These materials are made by dissolving the cellulose from wood pulp, cotton, and many other plants and then forcing the solution through a pin hole so that a very fine threat is formed. The thread is hardened and as many of these artificial fibers as are necessary to get the desired thread size are twisted together and the thread is woven into cloth. The artificial silks are classified according to the process used for their manufacture and it is a little more difficult to be able to recognize them than the natural fibers under the microscope.

In the original process bits of waste cotton were treated with nitric acid which produced gun cotton or cellulose nitrate. The nitrated cellulose was dissolved in a mixture of alcohol and ether and the viscous solution forced through pin holes to make the fibers. As the alcohol and ether evaporate rapidly and may be recovered to be used again, the fiber becomes hard. This was then treated chemically to take out the nitric acid so that the thread will not be inflammable and explosive. The fibers are twisted together to make the thread. This process is known as the Chardonnet process and the artificial silk is called collodion silk, fig. 20. The fibers are seen to be quite smooth under the microscope and marked by heavy dark lines running along the fiber and the surface may be wrinkled from the rapid drying of it in air.

EXPERIMENT 123. Collodion Silk

Look at some rayon silks and try and find some fibers that are made by this process. It helps to make thin sections of the artificial silk fibers for identification. The collodion silk has crescent, oval or irregular-appearing cross sections.

Instead of using nitric acid the Cuprammonium method dissolves the cellulose in a solution of copper oxide in strong ammonia. The dissolved material is sprayed into fibers and the copper and ammonia removed leaving a brilliant fiber with fine, faint surface lines and with a round or oval cross section.

EXPERIMENT 124. Cuprammonium Silk

Try and find some rayon made by this process, fig. 20.

Viscose rayon is obtained by treating purified cellulose from wood pulp chemically to make it into cellulose xanthate and the fibers are recognized from their wrinkled appearance due to the fine lines running lengthwise. The cross sections are flattened and of irregular outline.

EXPERIMENT 125. Viscose Silk

Can you find a sample of this kind of rayon?

The fourth common process for making artificial silk turns the cellulose into cellulose acetate by means of acetic acid, which is the acid which makes vinegar taste sour and have its own odor. These fibers look much like the other artificial silk fibers but do not swell much when they are placed in water, as do the other kinds of rayon. When the fibers are burnt they have a different, rather more unpleasant odor.

EXPERIMENT 126. Acetate Silk

Look for some acetate artificial silk.

For complete identification special chemical methods are used and it takes quite a little training to become a textile microscopist. The different artificial silks stain differently with dyes which helps in their recognition under the microscope.

The transparent wrapping papers like Kodapack and Cellophane are made by a similar manner except that the solution of cellulose is forced through a narrow slit instead of a pin hole. Cellophane gives very interesting colors in Polarized light, the color depending on the number of thicknesses of cellophane used. Kodapack does not give as pronounced colors.

EXPERIMENT 127. Sheet Cellulose Products

Examine different kinds of cellophane—like wrapping materials.

Many other plant fibers are used commercially. Hemp fibers are reted out of another plant much like linen fibers were described as coming from flax. The fibers look much like linen but the center hollow shows more clearly, fig. 19. These fibers are coarse and strong and used for making rope.

EXPERIMENT 128. Rope Fibers

Examine the fibers from a rope and compare with the other fibers you have just seen. Also examine the fibers from some burlap or gunny sack and you will see that they are quite similar but they are of another material called Jute. The Jute fibers are smoother than those of linen and often sharp pointed. Nodes are not found on Hemp and Jute fibers.

It is easy to make permanent preparations of textile fibers by drying them in the air and mounting in balsam under a cover glass.

CHAPTER 17

The Use of the Microscope in the Paper Industry

The use of the microscope in the paper industry is as important as it is in the textile industry. We use tremendous amounts of paper every day. It takes tons to print the daily newspapers, and a great deal is used for advertisements, magazines and as writing paper. Each use requires a different kind of paper and the microscope is used to identify the kinds of paper and to study their surfaces to see how they take ink and how they may be improved.

Much of the paper is made from wood pulp by chemical or mechanical treatment. The chemical method uses chemicals to separate the cells of the wood and to bleach them. The cells are then pressed into paper with rollers. Other materials may be added to obtain special kinds of paper and the spaces remaining on the surface between the cells may be filled with a sizing. Mechanically prepared fibers are obtained by grinding the wood between stones under water.

To examine paper one takes a small bit, about ¼″ square, and places it in a drop of water on a slide. It is gently rubbed from the center toward the edge with a dissecting needle to separate the fibers. When enough fine fibers have been separated the preparation is covered with a cover glass and studied under the microscope. For positive identification one must use special stains but we can learn much by looking at samples from different kinds of papers.

The mechanical process is the cheaper and is often used for making newspaper. The wood cells are badly broken and frayed by the process. The chemical process separates the cells without quite so much injury to them and is used in making better grades of paper.

EXPERIMENT 129. Chemical and Mechanical Paper Pulp

Examine several paper samples and try and decide whether the cells were separated by the mechanical or chemical method.

Two types of wood are used, the coniferous such as spruce, fir, pine and hemlock; and the non-coniferous like the bass, beach, birch and maple. The cells from the coniferous wood are tracheid cells like fig. 21A with thin walls and have a single or double row of dots, bordered pits, irregularly spaced on the surface. In cross section they are polygonal. The non-coniferous wood pulps have long tapering fibers with no surface markings and vessels, fig. 21B which are several times larger in diameter than the fibers and more or less covered by rows of pits or perforations. Sometimes they look like fine sieves.

EXPERIMENT 130. Coniferous and Non-Coniferous Paper Pulp

Which of the paper samples that you have prepared are from coniferous and which from non-coniferous wood? Papers from non-coniferous wood are less common and usually feel to be of a better grade as you handle them. If you look at a number of different papers you will find some of the non-coniferous pulp.

Brown wrapping paper is not bleached as much as white so that the fibers are not weakened and the finished paper is stronger. You will see on examining it that the fibers are not so completely separated from each other and the brownish color is due to the woody nature of the cell walls.

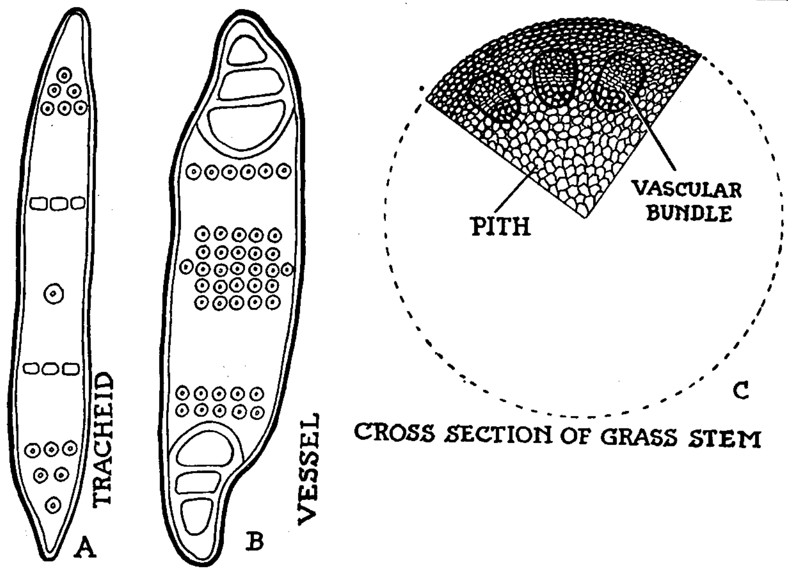


FIG. 21

EXPERIMENT 131. Unbleached Paper

Are paper bags and brown wrapping paper of the same composition?

Heavy, yellow pasteboard often contains cells from the walls of grass stems which have been ground. The cells are thin and tapering with hollow centers. Sometimes you will find groups of a dozen or so flat cells fitted together just as they were in the plant stem.

EXPERIMENT 132. Cardboard and Strawboard

Look at yellow and dark cardboards from packing cases and see whether some of them contain straw.

The better papers are made from old linen and cotton rags. If you examine some good writing paper you can make out the linen and cotton fibers, fig. 19, although you will find that they are badly broken and frayed from the process of breaking up the cloth into fibers. These longer textile fibers make a stronger paper, and do not rapidly turn yellow with age or with exposure to light.

EXPERIMENT 133. Linen Paper

Look at some good writing paper or at a bit taken from the corner of a bookkeeper's ledger and estimate how much of it is linen fibers and how much cotton. Do you find any wood pulp fibers present?

The fine, glossy papers used by the better magazines for fine halftone pictures are sized to give them a good surface. Some papers are sized with starch and this is easily determined by noting whether or not the surface turns blue when you add a very small drop of iodine.

EXPERIMENT 134. Paper Sizing

To examine the surface coating scrape it off very carefully with a sharp razor blade and mount the scrapings in water for microscopic examination. If they look like starch granules test by running a little iodine under the cover glass. The sizings of starch are usually cooked so that you cannot easily recognize the grains. If the particles look like crystals they may be gypsum, if they are irregular they may be talc or clay.

The fillers used with the fibers in the paper are harder to study but you can see them in your preparations of the fibers. It takes an experienced microscopist to be able to identify them, but that is part of the training of a chemist for the paper industry.

If you wish to keep your preparations, dry and mount them in balsam. It is interesting to stain them with the dyes that come with your set, or with colored inks or any other dyes that you may have about the house.

CHAPTER 18

Other Applications of the Microscope

Only a few of the interesting uses for your microscope have been mentioned in the chapters of the manual. You can do many more experiments with the subjects of each chapter and many other objects may be examined. Nearly everything in your house and yard can be looked at and many of them will be surprisingly interesting. Here are a few suggestions:

EXPERIMENT 135. Sound Groove in a Phonograph Record

How are the grooves formed in a phonograph record? Are the grooves of low toned parts of the record the same as those of high tones? those of a tenor and a bass singer? those of a violin and a band?

EXPERIMENT 136. Spices and Their Adulteration

Examine the spices in the pantry and see how they look. You will find some of them contain your old friends the starches. Cheap spices are diluted more with starch than expensive ones. Is your mother getting the best buy in each for the price she pays for them? The use of oil cleared preparations (Chapter 8) and staining with iodine will aid your examination of spices.

EXPERIMENT 137. Parts of Insects

A collection of slides showing the different kinds of insect mouth parts, wings and legs is very entertaining and quite easily prepared.

EXPERIMENT 138. Designs of Diatoms

One can make designs on a slide by carefully arranging different kinds of diatoms from the diatomaceous earth in your set by means of the forceps and needles. Some people have made these designs with over a hundred diatoms and they look very nice when viewed under the low power of the microscope.

EXPERIMENT 139. Cigar and Cigarette Ash Collections

Some boys make collections of cigar and cigarette ashes either keeping them in boxes or making permanent mounts with balsam and other boys make sets of soil samples. Perhaps you remember how Sherlock Holmes used cigar ashes to trace the culprit.

EXPERIMENT 140. Snow Flakes

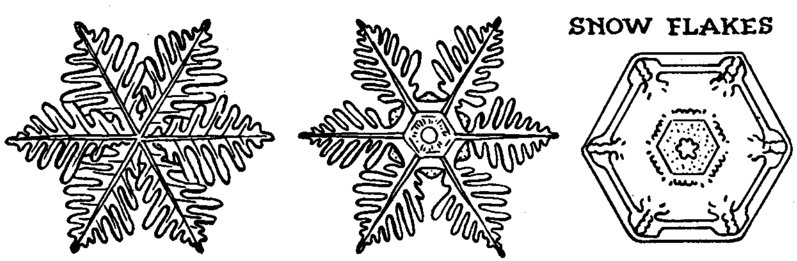


FIG. 22

On a winter day take your microscope out doors and catch snowflakes on slides as they fall. You will find that they are beautiful and often each one is different, fig. 22. Mr. W. A. Bentley made a hobby of photographing the forms of snowflakes and you will find an interesting, illustrated article by him in the January 1923 National Geographic Magazine.

Another interesting way of discovering other things to do with your microscope is to ask your family doctor, or a chemist friend how they use their microscope. A teacher of biology or natural science will be able to show you a great many uses of the microscope and tell you of many interesting objects.

CHAPTER 19

Detective Work With the Microscope

Right now the most spectacular use of the microscope is in detective work and almost everybody has read of how the police have solved by this means crimes that would otherwise never have been solved. A woman was found dead in New York City and it was suspected that she was murdered. The only clue was a bit of cord which was taken to the laboratory, identified as a kind used by upholsterers, traced to the manufacturer and finally to where it was sold. The police then found out who had used it and ultimately found and convicted the murderer. The microscopic examination of the cord helped solve the crime which otherwise might have gone as a perfect crime. Another interesting case was the identification of a burglar because on his clothes were found the burrings made from drilling a safe and the microscope showed that these were the same as those left near the safe.

Successful detective work requires the detective to know how to use the microscope, all of the methods for preparing objects for study with it, and to have such a wide knowledge of how materials look under the microscope that he can recognize the unknown quickly and then prove that he was right by comparing the unknown material with known material. Your study of starches, hair, pollen, fibers and fish scales is good training for detective work.

There are many experiments you can do of this kind.

EXPERIMENT 141. Identifying Soil Samples

Take a little of the dirt from the edge of a shoe and see what it looks like under the microscope. Look at different specimens of soil from different places and see if you can find out by comparing them with that on the shoe where the owner of the shoe had been.

EXPERIMENT 142. The Vacuum Cleaner Detective

Take a little of the dust from the vacuum cleaner bag and see how many different things are recognizable in it and then see if you can figure out where they came from. You may find parts of insects, textile fibers, hairs, etc. Would the use of a vacuum cleaner at the scene of a crime be helpful in finding clews?

Handwriting is always different because each person makes the letters in a peculiar manner. Each typewriter has slight differences in the form of the letters. Different typewriter ribbons give slightly different impressions. Sometimes the dot on the *i* is of different size or worn so that it is not round or may barely show. Different machines have the period so that it may have a slightly higher or lower position in the line. Some people habitually strike one letter harder or less hard so that you can recognize their writing even though they use different machines.

EXPERIMENT 143. The Handwriting Expert

Examine different kinds of handwriting with your hand lens and with your microscope until you can find the peculiarities that would permit you to say two samples were, or were not, the same. Have a friend try to disguise or change his writing and see if there are not still some telltale peculiarities that will show whose it is. Do you think that anyone could completely change his writing?

EXPERIMENT 144. Typewriter Detection

Study different kinds of typewriting until you can tell whether two samples were made with the same machine.

The microscope may be used to determine whether a document has been changed. Erasures that could not be seen with the naked eye roughen the surface of the paper so that you can see the difference with the microscope. Hold the microscope lamp above the paper so that the rays of light fall on the paper at an angle.

EXPERIMENT 145. Can Hand Writing Be Disguised?

Try and make a very careful change in some writing and then see how easily it can be discovered with your microscope.

EXPERIMENT 146. Safety Paper

Examine a safety check with the over all printed surface to see the design. Note how the least change or erasure shows up when you look at it with the hand lens or the microscope.

Artists using oil paint make strokes with their brushes which show their own styles. These are as different as handwriting.

CLASSIFICATION OF FINGER PRINTS

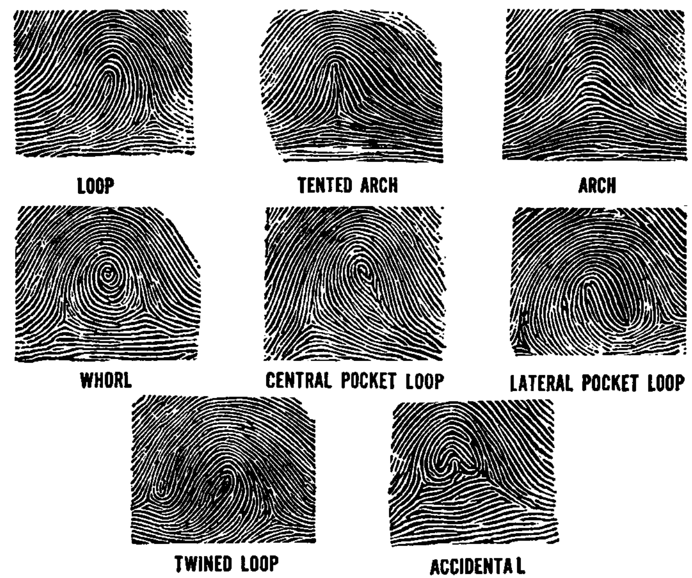


Fig. 23

EXPERIMENT 147. Oil Paintings

Examine some oil paintings and note the brush marks and see if different painters may be recognized by this method. If you are very careful you will not injure the painting.

Fingerprints are very important and fascinating. Put your finger on a piece of paper. Now if you shake a little black powder on it it will stick to the print and you can blow off the excess and find a reversed print of the ridges of your finger looking like those of fig. 23. You may use a little charcoal or very fine shavings from a soft pencil for black powder. If the fingerprint is on a dark object use white talcum powder to develop, or bring out the print. No two people have the same fingerprints, therefore, the prints make identification certain as many lawbreakers have learned to their sorrow. You may make prints of your own and your friends fingers as you did in experiment 7. Many people are having their fingerprints filed with the Department of Justice in Washington so that they may be certainly identified in case they have an accident anywhere in the world. They can then make sure of documents if they sign them with a fingerprint as well as their signature. Such fingerprints are filed separately from those of criminals at Washington.

EXPERIMENT 148. Kinds of Finger Prints

Examine different fingerprints to see how they are simiiar and how different. The hand lens will help you.

EXPERIMENT 149. The Home Detective

Examine the icebox, the door knobs, etc., to see which members of your family have used them.

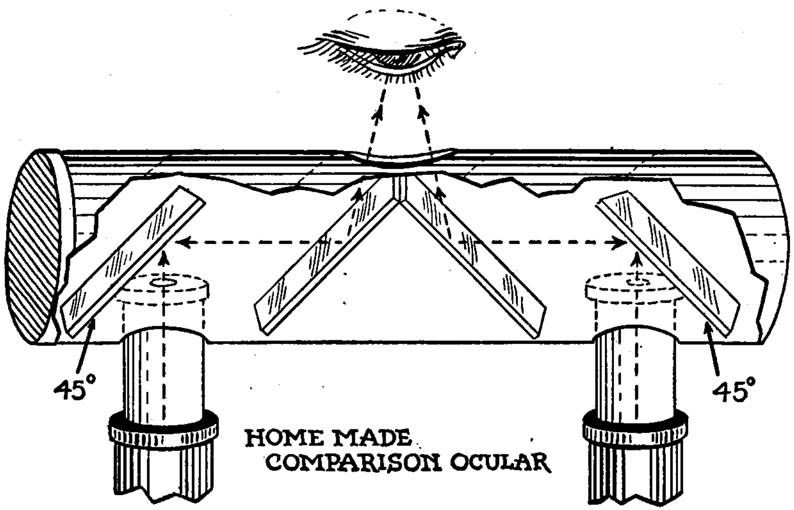


Fig. 24

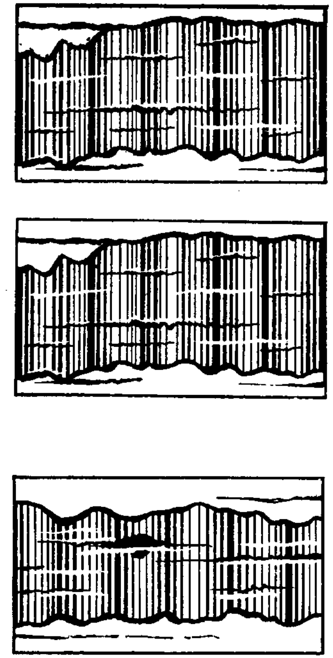


Fig. 25

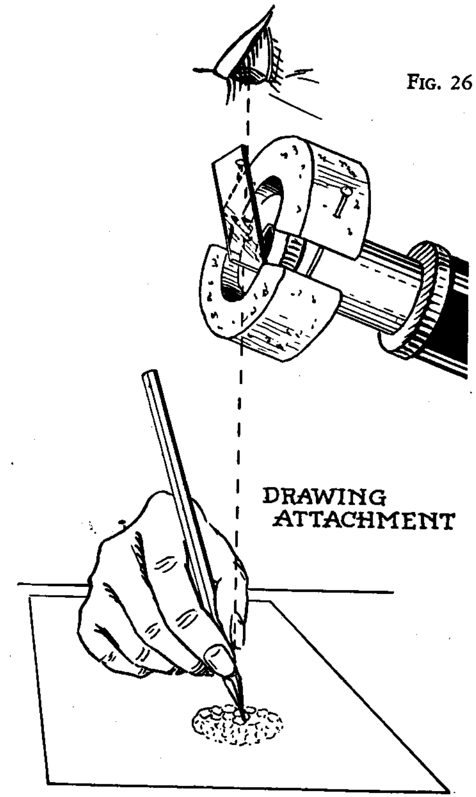


Fig. 26

When a bullet is shot out of a gun the barrel of the gun makes marks on the surface of the bullet and each gun barrel makes a different signature. By comparing the unknown bullet from the scene of the crime with one known to be shot in a particular gun it is possible to determine whether or not the same gun was used. For this work two microscopes are used with each bullet on a microscope. A comparison eyepiece is fitted to both microscopes so that the images of both bullets are seen side by side. By turning the bullets one can see whether or not the grooves are the same. If you can borrow another microscope from a friend, you can make a comparison eyepiece similar to that shown in fig. 24. The round cardboard tube may be rolled up from stiff paper or a mailing tube may be used. It should be long enough to permit the two microscopes to stand side by side. Cut the holes just big enough for the eyepieces of the microscopes to pass through and set the two end mirrors at 45° like those in the picture. The ends are then covered with stiff dark paper to keep out light not coming from the microscopes. A single hole is cut on the opposite side of the tube from that of the two holes, and the two mirrors are fastened together and tilted until you can see the image from both microscopes side by side. With such a comparison piece you can easily compare any two objects such as bullets to see if the markings are exactly the same. The telltale markings on three bullets are shown in fig. 25. Two of the bullets were shot from the same gun and the other from a different gun.

You will wish to have some method for making drawings directly from your microscope both for permanent record and for making comparisons in case you do not have access to two microscopes. A simple drawing attachment, or camera lucida, is illustrated in fig. 26. Cut a large cork in two lengthwise and hollow out the two flat surfaces until they fit closely around the eyepiece of your microscope. They may be held together on the microscope by two long pins or nails. Cut a groove in the cork so you may put a clean slide which is first broken in half into it so it will hold the slide at 45° to the body tube of the microscope, as shown in fig. 26. A more simple method would be to attach the slide with adhesive tape.

To use the drawing attachment tip the microscope at the inclination joint until it is as near horizontal as possible. A weight, such as a book, may have to be placed on the stand to keep it from falling over. Place the slide you wish to draw on the stage, use the stage clips to hold it in place and look down the microscope as you have before, adjust the light with the mirror and focus the microscope. Then place your eye close to the slide, as shown in fig. 26, and you will see the object on the microscope reflected by the cover glass. You can also see through the cover glass, your pencil held on a piece of paper directly under the attachment. With a little practice you will be able to balance the light on the mirror and that on the paper so that you can see both at once. Then you may make an accurate tracing of the object on the paper. The drawing attachment is used to get the outlines, is taken off and the details filled in as you examine the object, without the attachment.

CHAPTER 20
The Use of Polarized Light

A beam of light acts as if it were a wave of some sort in which the vibrations are at right angles or crosswise to the direction of the beam. A beam consists of many waves going together in the same path but with their vibrations in all possible directions to the path. When such a beam of light is passed through a polarizing substance the waves are so combed that only those vibrating in the same direction can pass through the polarizer, and we say that the light is then polarized. If we hold a second polarizing filter in front of our eye and look down the beam of polarized light toward the first polarizing filter and turn the filter before our eye we find the light to gradually become darker until we reach a position of the second when the light is dimmest, continuing to turn it we find the light gets brighter and then the brightening and dimming of the light repeats. When the axis of the second polarizer filter is at right angles to that of the first, the polarized light is blocked and cannot pass through. Placing the second at 45° passes half of the light and when the axes are the same the light goes through both filters.

The Nicol prism is used to separate the light rays so that only those vibrating in the same plane can pass and these prisms are very expensive. Recently E. H. Land discovered how to arrange many very small crystals of certain salts of quinine in a transparent material so that large polarizers can be made at considerably less cost. This material is called *Polaroid*. The *Polaroid Jr.* in your set will not polarize the light so completely as the more expensive Polaroid, but is satisfactory for our experiments.

Light reflected from various substances is more or less polarized. When the reflecting substance is non-metallic and at 33° to the beam of light, quite complete polarization occurs.

EXPERIMENT 150. Polarization by Reflection

Take the round element of Polaroid Jr. from your set and look at various objects through it as you hold it in front of your eye. As you look at them rotate the disc and you will notice that in certain positions the glare of reflected objects disappears and you can see them clearly. If you are near a lake or the ocean you will find that much of the light reflected from the waves is polarized, because you can cut it out by turning the Polaroid Jr. filter to the proper position.

This property of the Polaroid products is of important use in making glasses for outdoor wear and special Pola-Screens are now used in front of the camera lens to reduce the intensity of reflected light which obscures the details to be photographed.

EXPERIMENT 151. The Use of Two Polarizing Filters

Hold the long Polaroid Jr. element from your set between you and a source of light with one hand and the round element in front of your eye with your other hand. Turn the round element as you look at the long one and you will find a position of the round one which makes the long one nearly black and another position that passes the light through both. The position of the elements with their axes at right angles to each other does not block the light completely, because a little purplish light still passes through. This will not make any difference to our work and makes the material possible in our sets even though the more perfect polarizers would be too costly.

This experiment illustrates the principle that has been suggested for use on automobiles. The Polaroid over the lights of the cars would be at the proper angle to that placed in the windshields and the light of an approaching car would be barely seen from within the car instead of nearly blinding the driver.

EXPERIMENT 152. Using Polarized Light with the Microscope

Place the long Polaroid Jr. element under the stage of your microscope so that the filter is in the center of the hole in the stage. The clips under the stage will hold it in place. The light reflected from the mirror will be polarized as it passes through the Polaroid Jr. into the objective of the microscope. It does not look very different to the eye, but when you place the round element on top of the ocular and rotate it you will find that you can make the field look very dark when it is turned so that the axes of the two Polaroids Jr. are at right angles.

EXPERIMENT 153. Potato Starch in Polarized Light

Scrape off a bit of raw potato starch onto a clean slide and mount it in a little water under a cover glass. Place the Polaroids Jr. so that the field of the microscope is dark as in the last experiment and then put the potato starch under the microscope. When the microscope is properly focused you will see bright colored crosses in the potato starch grains. These disappear when you remove the filter from the eyepiece, or when you turn the filter to other positions.

The fine structure within the starch grain sets up interference of the polarized light as it passes through it and causes some of the rays of light to be differently polarized and to interfere with each other. Then they can pass through the filter on the ocular, called the analyzer, and the colors you see come from the interference of the light rays with each other. Many kinds of substances have similar effects on light because of their fine structure and such substances are said to be doubly refractive. The fine structure is too small to be resolved by the microscope but by analyzing the color patterns produced with polarized light much may be learned about them.

EXPERIMENT 154. Identifying Starch with Polarized Light

It is often easier to detect starch with Polarized light than without it. Starch is used in yeast cakes, some pills and often as an adulterant of coffee and spices. Repeat these experiments using polarized light to see how much easier the identification becomes with the polarized light.

Most living substances have a doubly refracting fine structure and give nicely colored images with polarized light. You will wish to examine most of the objects you have looked at before with polarized light. Here are a few experiments which will suggest many others to you. When the colors are not brilliant, try different thickness of the material until you find the best thickness for each substance examined. Placing the tint plate (Exp. 162) between the polarizer and the subject frequently enhances or changes the colors. Try various thicknesses of the tint plate.

EXPERIMENT 155. Plant and Animal Hairs with Polarized Light

Mount some fine hairs from a leaf in water and you will usually see colored images of the hair. Animal hairs show different colored patterns with polarized light. (Chapter 6).

EXPERIMENT 156. Polarization Images from Wood

Slices of wood must be extremely thin to affect polarized light in the way intended. The appearance is more readily seen if the wood is dried and mounted in balsam.

EXPERIMENT 157. Sections of Shells, Horn, Bone and Teeth

Break or cut as thin a shaving as you can from a bit of horn, shell, bone, tooth or finger nail and you will find them to be very interesting when viewed with polarized light and your microscope. To make really good preparations of these heavy materials, a section is cut with a hack saw as thin as possible and then ground smooth on one side on a carbordundum stone with water. This is dried and cemented with balsam to a slide and then the other side ground until the preparation is thin enough to show well under your microscope. It takes time and patience, but the preparations are worth it. When finished dry again, add more balsam and make a permanent preparation by adding a cover glass.

EXPERIMENT 158. Fish Scales

Fish scales give pretty colored images in polarized light especially after they are cleared in xylene and mounted in balsam.

Textile fibers require polarized light for their complete study. The artificial silks may be separated with this aid when they appear otherwise much the same.

EXPERIMENT 159. Cotton, Silk, Wool and the Natural Fibers

Examine the natural fibers mentioned in Chapter 16 with polarized light to see what kind of color patterns they show.

EXPERIMENT 160. Separating the Artificial Silks with Polarized Light

Acetate artificial silk does not polarize well, but viscose, cuprammonium and collodion silks give good colors in polarized light. The collodion giving the brightest colors.

EXPERIMENT 161. Cellulosic Wrapping Materials

Look at a little Cellophane and notice the bright colors. Try a little Kodapack and notice that it shows very little color unless you use a number of thicknesses (10-15).

Thin, transparent, doubly refractive materials like Cellophane and Kodapack create interference colors in accordance with the number of layers that the light passes through. Try one, two, three and more layers and notice the different colors produced when the Polaroids Jr. are set to give the darkest field.

EXPERIMENT 162. Retardation Tint Plates

Find how many layers of material are necessary to make a difference of just one color. The materials like Kodapack which are weaker optically are better for this experiment even though more layers are required. Standard plates are made for use with the microscope which change the color a certain amount and these are used when making analyses. You may find your material wrapped around various products or may buy small amounts of the sheets from a stationery store. Interesting designs may be made by mounting bits of Cellophane on a slide. Thin pieces of mica are useful to show colors. Try various thicknesses. Try your tint plate *with* other objects. Tint plates having a known color change are used in analytical work.

EXPERIMENT 163. Effect of Rotating the Analyzer

Look at a pattern made of several layers of Cellophane and as you watch rotate the round filter on the ocular and you will see a regular change of the colors.

EXPERIMENT 164. Examination of Minerals with Polarized Light

Small bits of minerals give beautiful colors when looked at under the microscope with crossed Polaroids Jr. Thin ground slices, made as described before with bone, are best but small broken fragments may be used. Examine them with and without polarized light. The following minerals are suitable objects: various agates, serpentine, carbonate of lime, some kinds of marble and sandstone, granite, mica, quartz containing rocks and the selenites. You may be able to find some of these near where you live.

Crystals frequently appear like jewels when you look at them with your polarizing set and as you turn the analyzer on top of the ocular you will find an unending series of colors.

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