# MICROSCOPE


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# THE MICROSCOPE

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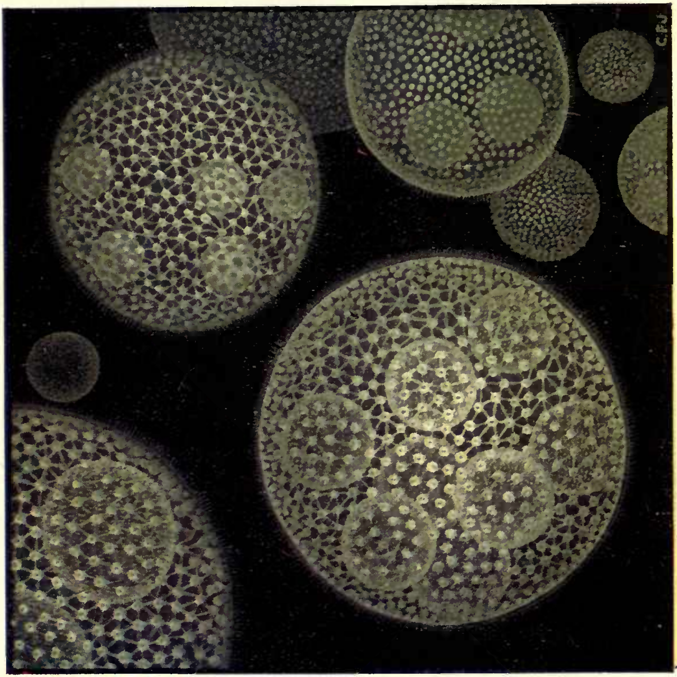

From a water-colour drawing by [G. Fisher-Jones

Volvox

# The Microscope

BY

CAPTAIN ELLISON HAWKS

Author of "Stars," "Bees," "The Earth," Shown to the Children
"The Boy's Book of Astronomy," "The Romance of Water
in Nature," etc.; and Editor of Messrs. Jack's
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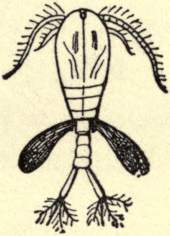

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TO

MY YOUNG FRIEND

JOHN

THIS BOOK IS AFFECTIONATELY

DEDICATED

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# CONTENTS.

# ABOUT THIS BOOK.

DEAR JOHN,

Many years ago I remember reading a fairy tale called, I think, *The Rose-Coloured Spectacles.* It told of a wonderful pair of spectacles which caused everything to appear different to the person who was wearing them. Things looked so very changed as seen through these rose-coloured spectacles and so many new features were discerned, that people came from far and wide to look through them.

Unfortunately the secret of the manufacture of the rose-coloured spectacles has never been discovered. An instrument has been made, however, which nearly approaches them, and actually surpasses them in the wonderful things it shows. This instrument is the Microscope, and in this little book I shall endeavour to help you to look through it and to see some of the wonderful things it reveals in the great realm of Nature.

Almost any object, no matter how commonplace, will show new features of interest when magnified. You will readily understand, therefore, that in this little book I cannot attempt to tell you how everything looks, as seen with the microscope—in fact, no one could write such a book. There are so many interesting objects to write about, indeed, that it has been difficult for me to decide what was to be included and what was to be left out. I felt, however, that you would like most of all to hear of what the microscope reveals in objects of everyday interest; that you want to know what such things as pollen and plant cells look like, and to learn exactly by what means a spider spins its web and a bee stings. Therefore, practically all the objects I have described are such as any one may see if he or she be the fortunate possessor of a microscope—even though it may not be a very powerful one. Not only may you see these objects, but from the little I have told you about them, you will be able to understand them, to know something of their life-history and of the part they play in Nature.

I feel sure you will join me in giving thanks to my friends who have kindly assisted me with some of the illustrations. To Mr. G. Fisher-Jones, F.R.M.S., for the very beautiful coloured plates so accurately and artistically drawn. To Mr. Chas. D. Holmes, Mr. A. E. Smith, Mr. E. A. Pinchin, Mr. W. Brough-Randles, B.Sc., Mr. W. Coles-Finch, Mr. J. Holmes; and to Messrs. Flatters, Ltd., and to Messrs. Pathé Frères. My indebtedness to Captain W. R. Booth and Mr. Chas. D. Holmes for reading over the proofs must also be mentioned.

Yours truly,

ELLISON HAWKS.

10 GRANGE TERRACE, LEEDS,
*November* 1919.

# THE MICROSCOPE.

## CHAPTER I.

## THE STORY OF THE MICROSCOPE.

### I.

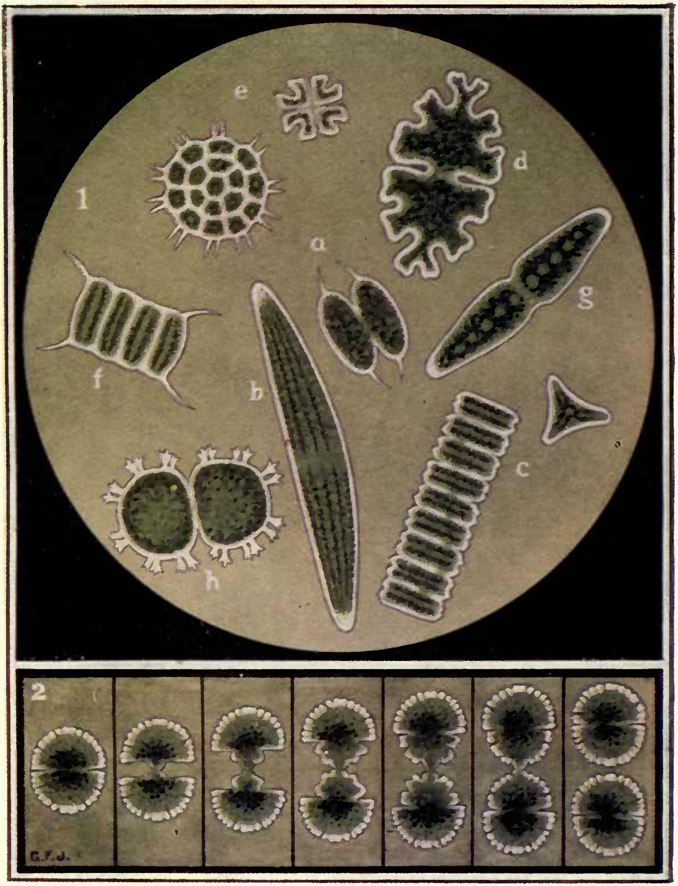
THE microscope derives its name from two Greek words, *mikros*, "small," and *skopeo*, "to see or observe." A microscope presents to the eye of its user a magnified image of the object under examination. The simplest form of microscope is an ordinary lens, such as a reading glass or pocket magnifier. With the help of a low-powered microscope we are able to magnify objects so that there become visible details which cannot be seen with the naked eye. By means of a more powerful instrument we are able to see objects which are otherwise quite invisible, and of the existence of which we should probably remain in complete ignorance but for the microscope.

The microscope may thus be likened to a window through which we are able to look upon a new and wonderful Fairyland. Here objects measuring no more than a quarter of a millionth part of an inch in size are revealed to us, and made to record themselves on the photographic plate. A drop of water from a pond may be so magnified that we find it is almost a world in itself, containing specimens of minute vegetable and animal life. The very construction and origin of these minute forms of life are often such as to present to us the most difficult problems, which even our cleverest scientists and chemists are unable to successfully and completely solve.

Again, a pinch of knife polish may contain microscopic shells, which are really the skeletons of minute creatures which lived ages ago. These shells are so delicate and beautiful in appearance that our greatest artists would gladly use them as patterns for designs if they could. So I might go on, pointing out to you the wonders which the invention of the microscope has laid bare to the gaze of all who care to look.

## II.

The actual date of the invention of the microscope and the name of its inventor are unknown. It has been said that magnifying glasses were known to the ancient Egyptians, but whether this was so or not now appears uncertain. In the first century, Seneca—the tutor of the infamous Roman Emperor Nero—noticed that if a globe of glass be filled with water, writing seen through it appeared larger than it really was. Galen, the learned Greek physician, tells us definitely that magnifying glasses were certainly not known to the Greeks and Romans in the first and second centuries. Much later—in the eleventh century—the Arabians seemed to have




From a water-colour drawing by] [G. Fisher-Jones

**1. Desmids**

(*a*) *Arthrodesmus*, (*b*) *Closterium*, (*c*) *Desmidium*, (*d*) *Euastrum*, (*e*) *Pediastrum*, (*f*) *Scenedesmus*, (*g*) *Tetmemorus*, (*h*) *Xanthidium*.

**2. Stages of division of a Desmid**

*Micrasterias*, forming two individuals.

known and used some form of magnifying glass. Beyond these few facts nothing of importance has been discovered of any early evidences of magnifying glasses, and until the thirteenth century very little appears to have been known about them.

In 1276, however, Roger Bacon—a Franciscan monk of Ilchester — presented his *Opus Majus* to Pope Clement IV. In this interesting volume Roger Bacon showed how crystal lenses could be used to make objects appear larger. "With these lenses," he said, "an instrument could be made, useful to old men and to those whose sight is weakened, for by means of it they would be able to see letters, however small they are, made large and clear. . . ."

In the days when Roger Bacon lived people did not understand science as we do to-day, believing in sorcery and witchcraft. They thought that any one who had discovered lenses such as those described by Roger Bacon must indeed have gone to the devil himself for assistance! It was ordered, therefore, that he should be cast into prison. His *Opus Majus* was hidden away—perhaps by some of his friends, but this we do not know—and remained lost until discovered in 1733, nearly five hundred years later. By this time a form of microscope had been in use for over one hundred years, and Roger Bacon was thus robbed of the credit of the discovery, as well as, perhaps, of the discovery of the telescope.

Many careful investigations have been made in the attempt to find who constructed the first microscope. It is now believed that it was made at some date between 1590 and 1609, and that the credit for the invention must be given to one of three spectacle makers of Middelburg in Holland—Hans Janssen, his son Zacharias, or Hans Lippershey.

## III.

One of the earliest accounts of the microscope and of observations with the instrument was given in 1665, by the celebrated Dr. Robert Hooke. It was published in a large volume called *Micrographia*, a copy of which is to be seen in the British Museum. Dr. Hooke describes his microscope as having a tube: " . . . for the most part not above six or seven inches long, though by reason that it had four drawers it could easily be lengthened as occasion required. . . ."

We shall shortly learn that microscopes are of two kinds, called simple and compound. The instrument used by Dr. Hooke was of the compound type, and is the same in principle as most of the microscopes of the present day.

Some few years after Dr. Hooke published his *Micrographia* another worker, named Leeuwenhoek, made a simple microscope, and in 1673 communicated some of his discoveries to the Royal Society. He did not describe his instrument, however, but when he died he left to the Royal Society a cabinet containing twenty-six of his microscopes. His work is of importance because it then came to be believed that the form of microscope he used—that is, the simple type—was better than the compound type advocated by Dr. Hooke. Because of Leeuwenhoek's work the compound microscope fell into disrepute, and no improvements in it were effected for a considerable time.

To Benjamin Martin is due the credit for many advances on the earlier models. In 1742 he made an ingenious microscope and gave it to George III., and this instrument is now in the possession of the Royal Microscopical Society. It was, perhaps, the best microscope of any made up to that time. Professor Quekett, a well-known microscopist, has described it, saying that it is about two feet high, and is supported on a tripod base. The body, three inches in diameter, is composed of two tubes, which can be raised or lowered. There are twenty-four lenses, and these have been very carefully constructed.

Martin was quickly followed by numerous other workers, and during the ensuing years the microscope rapidly developed. These early microscopes were very crude and imperfect, and were you able to see one you would probably be very puzzled to know what kind of an instrument it could be, even though you knew what a modern microscope looks like. As time went on, however, and the manufacture of glass lenses gradually became more perfect, microscopists were able to improve on the early ideas, and little by little the wonderful microscope of to-day was perfected.

The microscope may be said to be one of our most recent instruments, for its true principles were not generally known until about 1881.

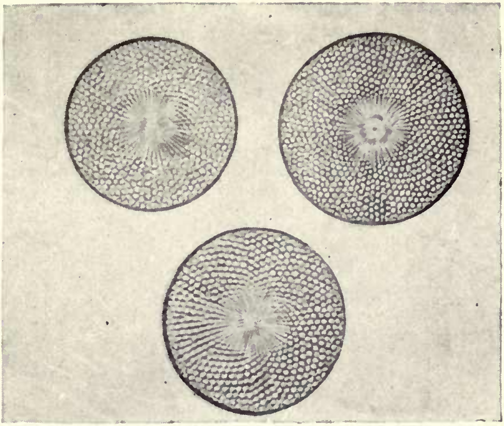
## CHAPTER II.

## THE PRINCIPLE OF THE COMPOUND MICROSCOPE.

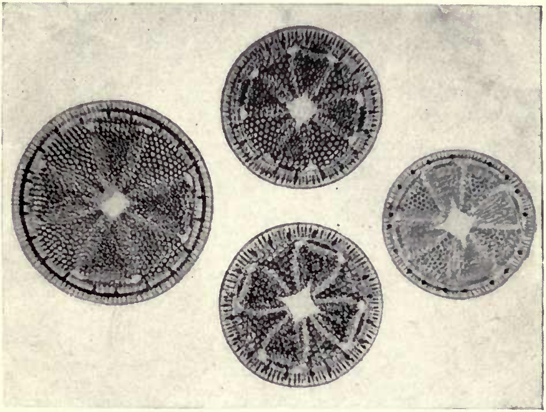
### I.

THE microscope—or indeed any magnifying glass—acts in the same way as the crystalline lens of our eyes and depends upon refraction. Refraction may be thus explained. When a ray of light passes through one substance—or medium, as it is called—into another of different density, the path of the ray is bent or refracted. Thus, a ray of light passing from air into water is refracted, because water is of different density to air. This may be clearly seen by putting a pencil or other object into a basin of water. The pencil appears to be bent or broken at the point where it enters the water (see *a*, Fig. 1). Why this should be so is shown in *b*, Fig. 1, where we see indicated the path of a ray of light coming from the end of the pencil to the eye. At the point where the ray comes out of the water it is bent; but the eye does not see this, and instead of our being able to perceive the true position of the end of the pencil, we seem to see it lying on an imaginary line. A ray of light passing through a lens is refracted in a similar

PLATE III



(a)



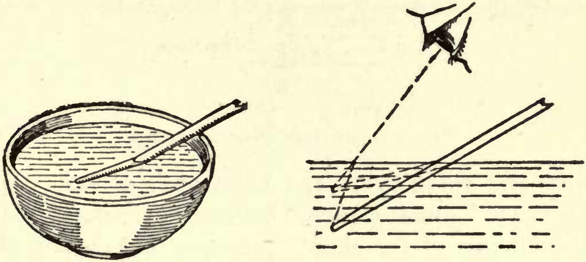
From photo-micrographs by] (b) [E. Cuzner, F.R.M.S.

DISC-SHAPED DIATOMS

(a) Craspedodiscus. (b) Heliopelta

manner, the amount of the refraction depending upon the nature and curvature of the lens.

Seneca did not try to understand why writing looked larger through a glass globe filled with water. Had he



(a) (b)

FIG. 1.—Experiment to illustrate refraction of rays.

done so he would have discovered that the curved surface of a globe bends inward the rays of light, because glass and water are more dense than air. It was by using this principle that the microscope was thought of.

A lens refracts the rays from the object under examination to an eyepiece, and it is here that the eye is placed. The point at which the rays from the lens gather is called the focus. At this point is formed an image of the object, and this is magnified by the eyepiece.

The principle may be explained in a rough way by comparing the lens to a funnel placed in a bottle. If placed in the rain the bottle is filled more quickly than would be the case if no funnel were used. A lens collects not raindrops but rays of light, and directs them to the eye of the observer (Fig. 2). By these means the eye is enabled to grasp more rays than it would do if a lens were not used—in other words, the object appears magnified.

The same principle is the basis of opera-glasses, tele-

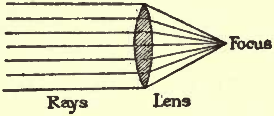



FIG. 2.—Lens collecting rays of light.

scopes, and spectacles. The latter were at first (about 1285) called "magic glasses," because the ignorant people did not know of the simple principle upon which they are based.

## II.

I have already mentioned that microscopes are of two kinds, simple and compound. A simple microscope consists of a single lens, or sometimes of two such lenses placed close together. It will magnify an object ten or

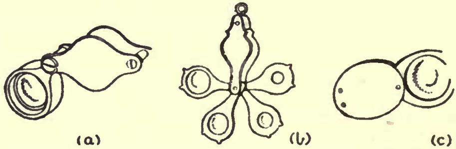



FIG. 3.—Pocket lenses.

twenty times. Simple microscopes are in everyday use as reading glasses and similar appliances. A more compact form is the pocket lens, three types of which are shown in Fig. 3. The form which is most useful is that shown at *b*, being fitted with three lenses and a "stop," or small hole, which enables a clearer image to be obtained. Different magnifications may be obtained by using the various lenses separately, and still greater magnification is possible by using a combination of two or of all three lenses. Leeuwenhoek's microscope was an improvement

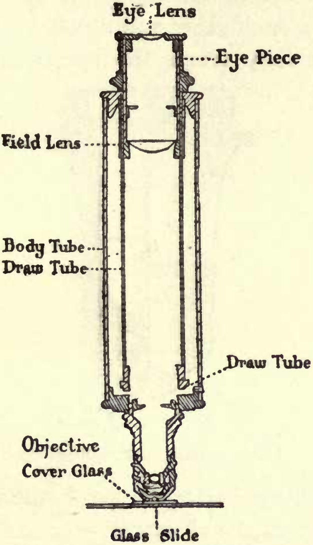



FIG. 4.—Section of a microscope showing the principal parts.

on a simple lens, for sometimes it magnified the object under examination 270 times.

The compound microscope, in which we are more particularly interested, consists of two sets of lenses (Fig. 4). The first set is placed at that end of the tube which is nearest the object to be examined, and is therefore called the "objective." The second set of lenses is situated at the other end of the tube and is called the "eyepiece," because it is nearest to the observer's eye. The objective collects the rays of light from the object under examination, bends them inward, and sends them to the focus. Here they form a minute image of the object. At the focus they cross each other and diverge into a broadening stream. Soon they reach the eyepiece, which further

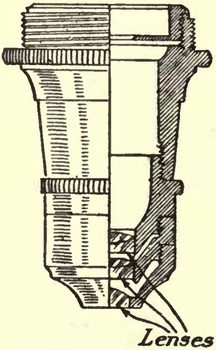
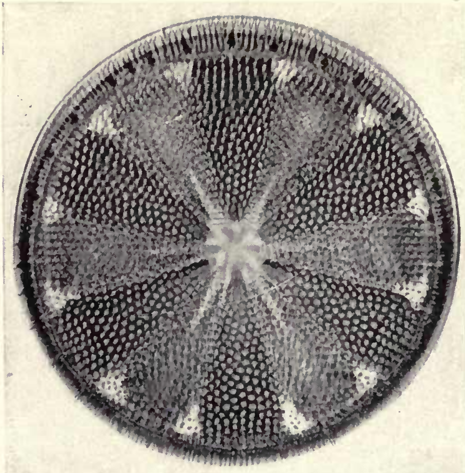



FIG. 5.—Microscope objective.

magnifies the image and again bends the rays and directs them to the eye of the observer.

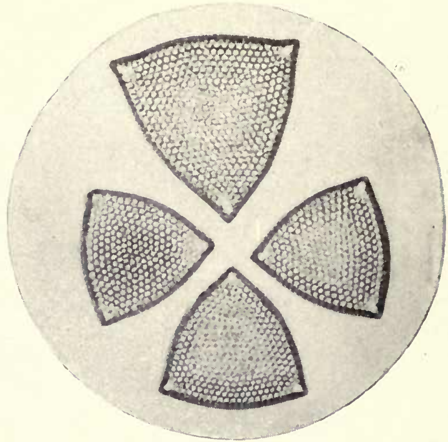
The objective (Fig. 5) is detachable and can be unscrewed easily from the microscope, so that another objective of lower or higher power may be put on in its place. The objective is the most powerful and the most expensive part of a microscope. In a very good instrument this one part alone may cost up to £25. An advanced worker with the microscope will probably require six, or more, objectives.

PLATE IV



From a photo-micrograph by] [A. E. Smith

(a)



From a photo-micrograph by] [C. D. Holmes

(b)

DIATOMS

(a) Heliopelta (b) Triceratium

In most microscopes to-day there is only one tube, and therefore only one eye can be used for observing. To some people this is often very fatiguing and causes a great strain upon the observer. In 1860 Wenham invented the binocular microscope, consisting of two tubes and two eyepieces (Fig. 6). By an ingenious device two images are formed from one object, and it is thus made possible to employ both eyes for observing. The binocular microscope is not generally used, however, most people finding the single tube instrument satisfactory.

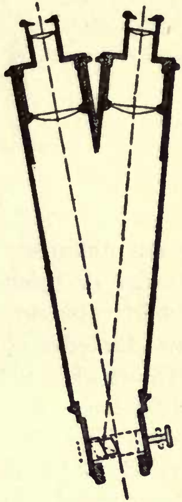


FIG. 6. — Section of Binocular Microscope.

## III.

From the description I have just given of the principles of the microscope you will readily understand that the glass from which the lenses are made plays an all-important part in its construction. It was because of a defect in the lenses that the microscopes of earlier days could not be developed beyond a certain point. To understand the reason of this, and the clever manner in which the difficulty was overcome, it is necessary to learn something of the two forms of lenses used. These are called "convex" and "concave" (Fig. 7). A convex lens is thicker in the middle than at the edges, and may be said to bulge outwards. A concave lens is just the opposite, for it is thicker at the edges, has a saucer-like hollow in the centre, sinking inwards. A convex lens bends or refracts rays inwards, but a concave lens refracts them outwards.

Because of the peculiar shape of a lens, and the conse-

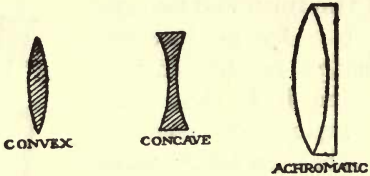



FIG. 7.—Three types of lenses.

quent difference in density of various parts where it is thicker or thinner, the rays are not all refracted to a similar amount. For instance, those rays which fall near the edge of a convex lens have not to pass through so much glass as those rays which fall on or near the centre of the lens. Consequently, on passing through a lens the rays follow different paths and do not all meet together exactly at the focus. A distorted and blurred image is then formed. This fault is called "spherical aberration." It can be overcome by fitting into the uncorrected lens a second lens, of a different shape from the original. When this is done all the rays are brought exactly to the same focus.

A second and more troublesome defect is a peculiar colouring—called "chromatic aberration"—caused by the lenses. We have been speaking of rays of light for the sake of clearness and as though they formed a simple stream of light. White light passing through a prism of glass issues from it as a coloured band. No doubt you have often noticed this when sunlight falls on a cut glass pendant of a chandelier or similar object. This band of coloured light is called the spectrum (Fig. 8). It contains certain colours which merge gradually into one another. They are always found in the spectrum in the following order: red, orange, yellow, green, blue, indigo, and violet. These colours are combined in white

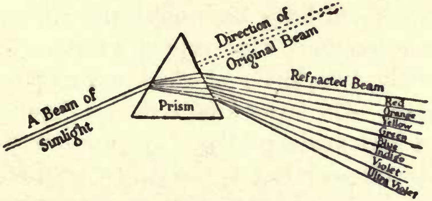



FIG. 8.—How the spectrum is formed.

light and are therefore invisible to us in ordinary circumstances.

When a ray of light passes through a concave or convex lens the same occurrence takes place as in the case of the prism. The white light is broken up into the above-mentioned colours. Each of these colours has what is called a different wave-length, that of red being much longer than that of violet. The consequence of this, in regard to the microscope, was that on passing through the lenses light was broken up into its component colours of varying wave-lengths, and each colour gave a faint but separate image of the object under examination. This was a great drawback, of course, because instead of the observer seeing a clear, well-focused image he saw a blurred image looking like "all the colours of the rainbow."

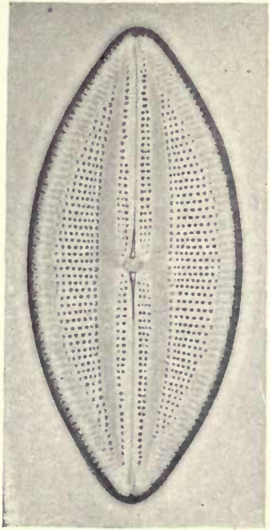
For many years opticians regarded it as impossible to overcome chromatic aberration. Clearly the remedy was to bring all the coloured images together at one focus—in other words, to make the rays all of the same wave-length. It was realized that unless this seemingly impossible task could be effected, the compound microscope could never be perfect. If several kinds of glass of different densities could have been used, the difficulty might have been overcome. This seemed a forlorn hope, however, for only two kinds of glass were known, crown and flint glass. The latter kind is denser than the former, and with a lens made partly of each it was possible to correct two colours; but as the light-waves of the other colours remained uncorrected, there was still formed a series of confusing faint images.

## IV.

About 1881 two Germans—Abbé, Professor of Mathematics at Jena, and Dr. Schott, who was interested in glass-making—began a series of researches and experiments, aided by their Government. Professor Abbé had studied optics since 1873 and worked on lines which were quite original. He was able to decide on paper the density he required the glass for his lenses, and also exactly the curve the surfaces needed. In 1884 a microscope was made which was not only constructed on new principles, but had lenses of a new kind of glass, called fluor-glass.

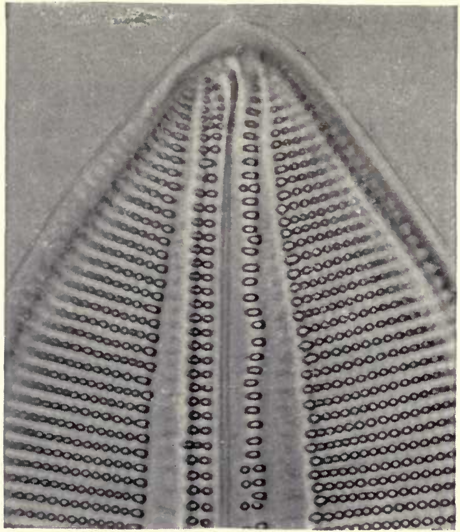
To understand more fully the value of this advance

PLATE V



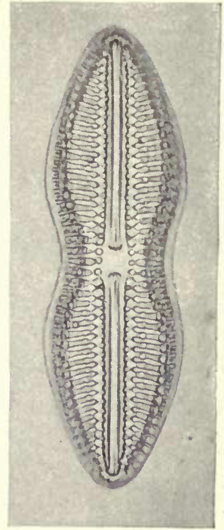
From a photo-micrograph by
E. A. Pinchin

(a)



From a photo-micrograph by] [A. E. Smith

(b)



From a photo-micrograph by
E. A. Pinchin

(c)

DIATOMS

(a) Navicula lyra. (b) The same, more highly magnified. (c) Navicula omata

in the construction of the microscope we must learn something more of the varying lengths of the light rays. We have already mentioned that violet rays are shorter than red rays. It is found that by employing the shorter rays more details in a minute object become visible. In fact, so much is this the case that by violet rays objects may be distinguished which are twice as small as those which can be seen by the longer red rays.

The violet rays are not the shortest of all known waves of light, for beyond them in the spectrum are the ultra-violet rays (see Fig. 8). These ultra-violet rays are most curious, for, no matter how long we may look at the coloured band of light from a prism, we cannot discern them. They are invisible to the human eye and have never been seen, for their length is so short that they make no impression upon our retina. The ultra-violet rays can, however, be photographed—or rather photographs can be taken by them—and so we know of their existence.

We can now better understand the next problem which confronted Professor Abbé. He knew that by means of the short violet rays objects which could not be seen with the long red rays might be made visible. He believed from this that if he could use the ultra-violet rays he would be able to make the microscope many times more powerful than it was, even with the violet rays. To attain his object he had to deal with rays he could not see, and there was no known kind of glass which was capable of refracting the ultra-violet rays in the same way in which crown and flint glass refract the ordinary rays.

Professor Abbé was not dismayed by such difficulties as these. After many experiments, the firm of opticians with whom he was associated succeeded in making lenses of molten quartz. These lenses could be used to refract the ultra-violet rays as required, but of course the image formed still remained invisible to the human eye. Even Professor Abbé could not render the ultra-violet rays optically visible, and so it is that objects can only be examined by these rays by photography.

Through the invention of quartz-glass lenses it is sometimes possible to examine objects which are only $\frac{1}{240000}$ inch in size.

## V.

A microscope consists of the following important parts, all of which are clearly indicated in Fig. 9.

(1) *The body*, generally a brass tube which carries, at the bottom, (2) *the objective*, and, at the top nearest the observer's eye, (3) *the eyepiece*. These parts are mounted on (4) *the limb*, as is also (5) *the stage*, which may be fitted with spring clips for holding the slide or object to be examined. In more expensive instruments a mechanical stage is fitted, which is easily moved from side to side or upwards and downwards by milled-head spindles and rackwork. Focusing is accomplished by (6) *coarse and fine adjustments*, and a light is reflected on to the object by (7) *a mirror*, fitted by a sliding clip to (8) *the tailpiece*. All these parts are mounted on (9) the *foot* or *base*.

If the object we are examining is thin and sufficiently transparent to enable light to pass through it, it is

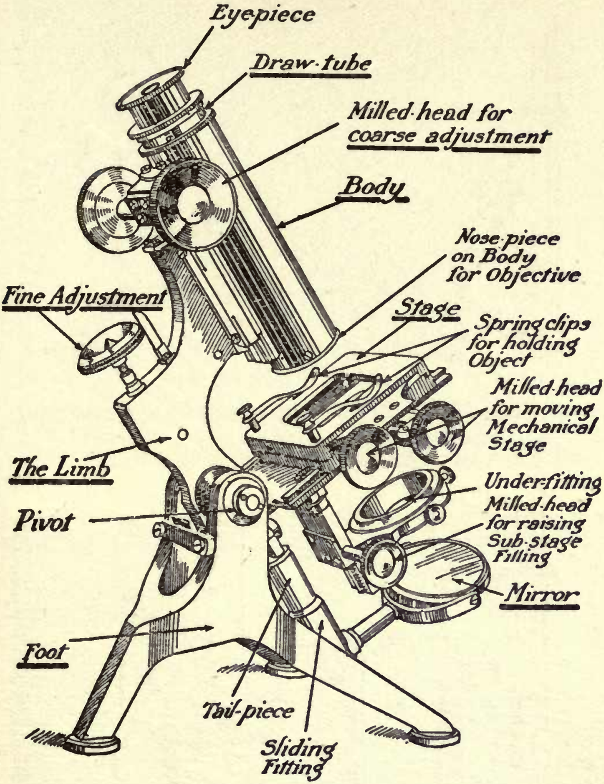



FIG. 9.—Illustration distinguishing the various component parts of a Compound Microscope.

placed upon the stage on a glass slip called a slide, and light is reflected to it by the mirror (Fig. 10). If the object is opaque, however, and it is impossible for light

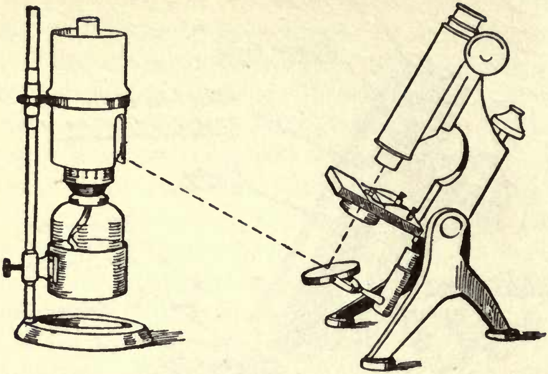


FIG. 10.—Illuminating a specimen by means of transmitted light.

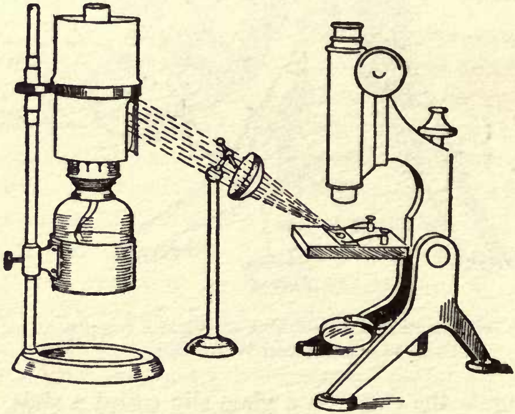
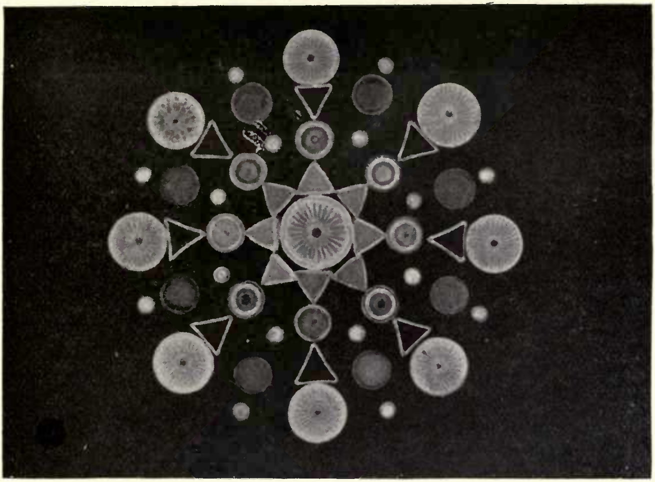
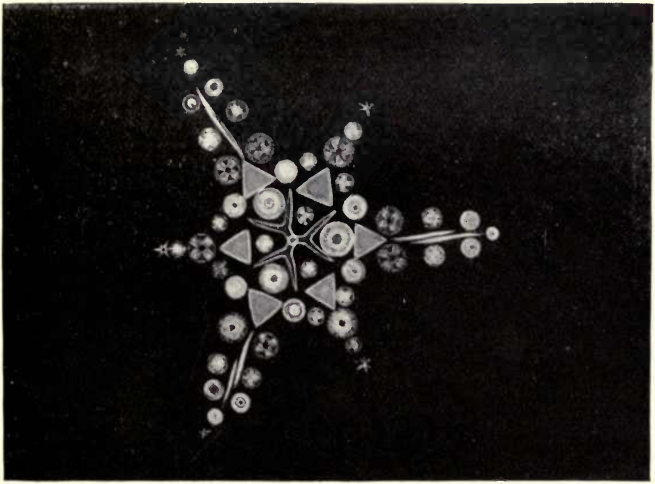


FIG. 11.—Illuminating a specimen by reflected light.

PLATE VI.





DIATOMS ARRANGED IN GROUPS

From photo-micrographs by] [E. Cuzner, F.R.M.S.

to pass through it, a condenser must be used instead of the mirror. The condenser consists of a lens—generally mounted on a separate stand—which throws a beam of concentrated light on to the object from above the stage (Fig. 11).

## CHAPTER III.

## WORKING WITH THE MICROSCOPE.

### I.

SOME people think that it is of no use studying any subject unless they can use the latest and most costly instruments. It is true that a really good microscope is expensive, costing anything from £5 to £50 or even more. It is not necessary, however, to expend even £5 on a microscope, for one could obtain much entertainment and do really useful work with a "home-made" microscope, which does not cost much more than 5*s*. Microscopes very suitable for studying the objects described in these pages are to be purchased from £1 to £5 second-hand. There are, of course, many objects—such as blood corpuscles and bacteria—for the study of which more powerful objectives are required; but we shall find that a simple form of microscope will reveal sufficient wonders to our gaze to employ us for many long evenings.

Galileo's telescope would be classed as a very crude instrument in these days—indeed, for a few shillings any one can make an equally powerful instrument. But in the hands of Galileo, this little "optick tube" explored the heavens, discovered the mountains on the Moon, the spots on the Sun, and changed man's ideas of the construction of the universe.

In his *Life and Letters* the famous scientist, Charles Darwin, says the student should always see what he can with a simple microscope before using a compound instrument. He further says that he would be inclined to suspect the work of a man who never used the simple instruments. When he set out on his celebrated voyage in the *Beagle*, Darwin took with him only a simple microscope, for it was his custom to use simple methods and few instruments in his work.

## II.

It is a good plan to spend the fine days of summer in collecting objects. After examining these, put away those which will keep, until the dark nights of winter, when sufficient time may be given to a lengthy and detailed study of each. For examination purposes the pocket lens will be found a valuable acquisition, especially if it is used correctly. It may seem unnecessary for me to tell you how to use a pocket lens, but for those unaccustomed to handling them it may be said that the best way to look at an object is first to put the lens close to the eye and then to bring it down, with your head following it at the same time, to meet the object under examination. When using a pocket lens it is sometimes desirable to have one hand free for dissecting, and the difficulty of working in these circumstances has been overcome by a simple device, called the " focostat " (Fig. 12). A single lens is mounted by a movable clip to the handle of the dissecting needle, and when once the lens has been moved to the correct focus, it is quite

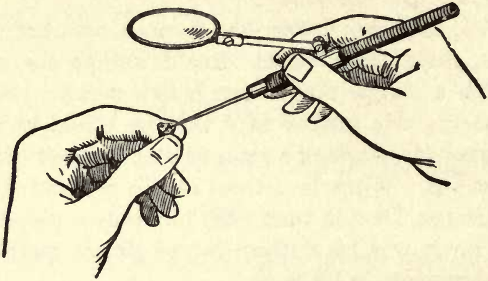


FIG. 12.—The Focostat. This is fixed to the dissecting needle, and leaves one hand free.

easy for us to see what we are doing with the needle point. Another way of working so that one hand is free

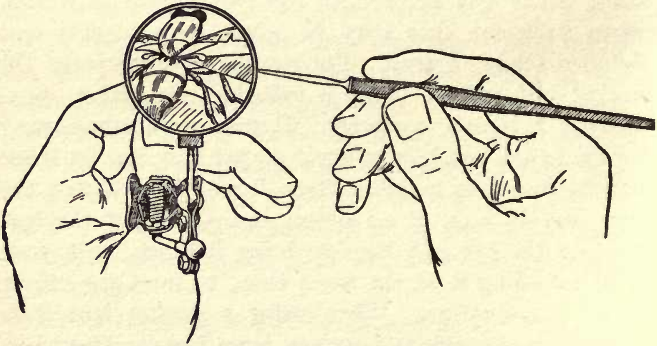
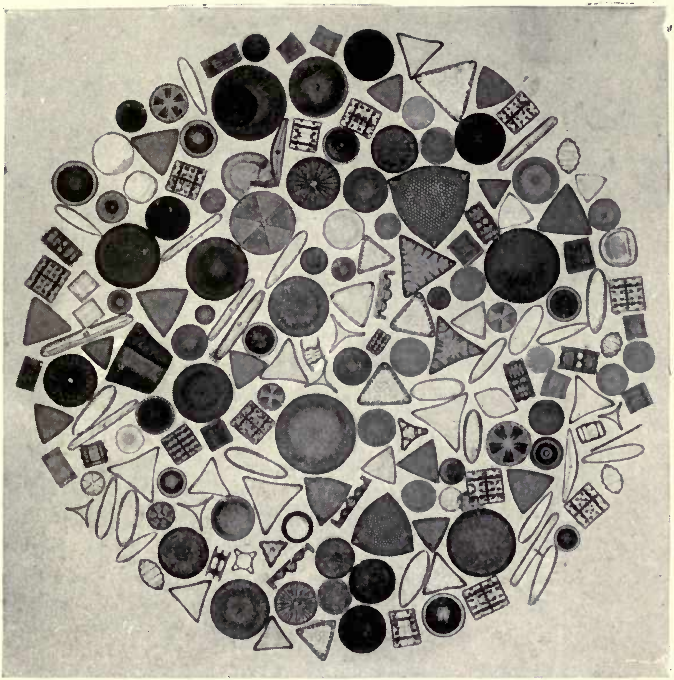


FIG. 13.—The "Third Hand" Magnifier.

is the "third-hand" magnifier, as it is called (Fig. 13). This consists of a lens which is attached to the thumb

PLATE VII



From a photo-micrograph by] [A. E. Smith

A GROUP OF DIATOMS

of the left hand by a clip, similar to the kind which are used for attaching shades to candles.

A notebook should be kept, and may include some record of where and how the specimens were obtained, and—later on, when they have been thoroughly examined with the microscope—an account of what is noticed about them. It is a good plan, too, to make as many sketches of the specimens as possible. It does not matter if you cannot draw or paint, for even the roughest sketch is better than none at all. It is found that by sketching an object we notice details which might otherwise escape our observation. For instance, could you describe to me exactly the kind of chimney-pot on your house ? Perhaps some of you could, but many could not. Had you made a sketch of your house at some previous time you would be able to say at once just what kind of a chimney the house had, because in making your sketch you would have had to study the detail of the chimney-pots in order to draw them accurately.

When using a lens or a microscope, it is best not to shut the eye which is not being used, as if this is done it will soon become tired with being screwed up for any length of time. With a little practice it is easy to train the mind to see only with the eye at the lens, even though the other eye is open.

## III.

When collecting specimens it is useful to take two or three glass tubes—the kind in which cachous are sold—and if possible a glass-topped box. If we are collecting specimens from a pond we take a small glass jar or a muslin net mounted on a stick (Fig. 14), and a little drag, made by inserting three or four wire hooks in a

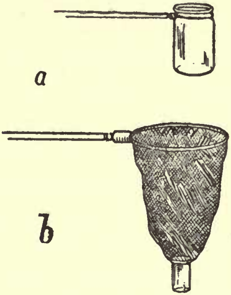



FIG. 14.—(*a*) Glass jar wired to stick. (*b*) Muslin net mounted on stick.

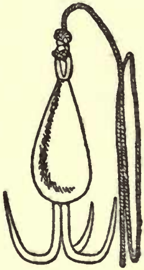


FIG. 15.—Drag for obtaining pond weeds.

piece of lead fastened to the end of a string (Fig. 15). With this we can pull to the side of the pond pieces of floating twig or weed.

A large bottle should also be taken, and if possible a second one, known as a "concentrating bottle." This is best made by obtaining one of those bottles with a metal screw-top, such as contain honey. Punch a number of small holes in the metal top and solder a tin funnel in the centre, the end of the funnel-pipe being a few inches from the bottom of the bottle (Fig. 16). Before screwing on the lid, stretch a piece of fine muslin over the top of the bottle. Water poured through the funnel in the bottle will now overflow through the holes in the lid, but the specimens it contains are prevented from leaving the bottle by the muslin.

FIG. 16.—Concentrating bottle.

Thus the more water we pour into the bottle the more numerous become the specimens it contains, so that we take home with us in our bottle specimens contained in bucketfuls of water.

Another useful instrument is a piece of glass tubing, about ¾ inch or one inch in diameter. One end is left open, but at the other a piece of fine muslin is fastened with an elastic band. The tube may be immersed in the pond and the water allowed to flow through it. The water passes down the tube and out at the end where the muslin is fastened. The muslin acts as a strainer, and retains minute specimens which may be easily transferred to a bottle by removing the elastic band.

Single specimens may be obtained by using a piece of glass tube open at both ends. Place one finger over one end of the tube and lower the other into the water so that the end comes over the specimen to be captured. If we take away our finger at the top of the tube, the water rushes up, carrying the specimen with it. By placing the finger at the top of the tube again, the tube may be lifted and its contents released into a jar.

## IV.

Objects for observation under the microscope may be divided into two classes. The first are those which do not require any preparation and may be observed at once, such as simple plants. The greater number of objects fall into the second class, however, and are those which must be prepared and treated before all the details of their structure may be made out. We can illustrate what is meant by this by taking the leg of some insect and, without previous preparation, observing it under the microscope. We see nothing but a dark opaque body, looking like a silhouette, with possibly a few hairs or specks of dust attached. If the leg be correctly prepared, however, a very different aspect is presented. In the first place, it is cleaned and rendered transparent; it is then seen to be beautifully coloured, and every detail becomes visible. The delicate muscles and membranes of the joints, the sharp claws and soft pads are now clearly seen.

For the observation of the first class of objects a live box is the best. This consists of a brass cell something

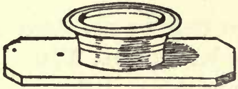
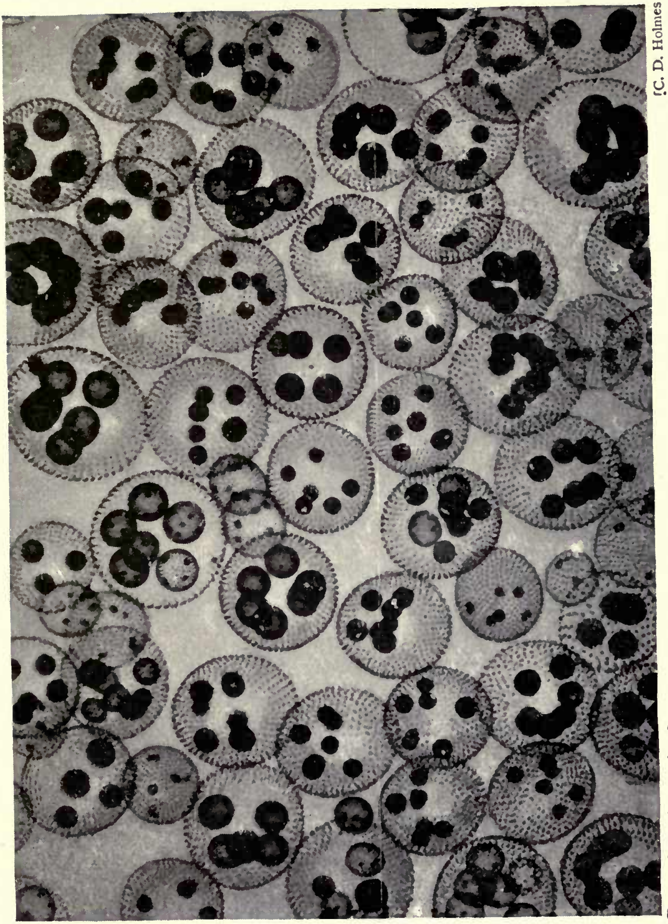


FIG. 17.—A live box.

like a pill-box with brass sides (Fig. 17). The bottom of the cell is formed by a piece of glass; over it is a lid or cover with a glass top which can be raised or lowered, so as to press on the bottom glass if required. This adjustment is very useful if we have a lively insect under observation, for we can gently press down the cover until the insect is trapped and held secure between the two glasses.

In observing an unprepared section of some fruit or plant it is best to place it on a glass slide and cover it with a drop of water, placing over it one of the thin cover-glasses used for the purpose. By doing so not only are particles of dust and dirt kept from the object, but

PLATE VIII



From a photo-micrograph by] [C. D. Holmes

VOLVOX GLOBATOR

also the microscope may be tilted to any angle required, without fear that the object will fall off the stage.

## V.

Although requiring patience and perseverance, the dissecting or cutting up of insects and small animals reveals many interesting objects and teaches us much about their internal structure. One of the first things to remember is, never to kill any creature unless you really intend to learn something from examination of its body. Secondly, always make quite sure that your victim is dead before you start operating.

Dissecting under the compound microscope is at first somewhat difficult. Not only do we feel awkward in dealing with minute objects such as the hairs or scales of insects, but also the objects become inverted, and changed from left to right when seen in the microscope. After a little practice, however, this state of affairs becomes quite natural. Dissections should be carried out under water, contained in a shallow trough. A porcelain dish, such as is used for mixing water-colour paints, or a watch-glass will do admirably for the purpose. More delicate work may be accomplished in a drop of water placed on a glass slide.

If we are anxious to learn what is inside an insect, such as a bee or a fly, and the object is too large to be dissected under even the lowest power of our microscope, we may carry out the first part of the operation under a simple magnifying glass. This should be firmly mounted in a temporary stand, thus leaving both hands free for operating. Having cut the insect open, extracted its internal organs and separated the limbs from its body, we may proceed to examine them with the higher powered microscope.

When insects have been killed for any length of time their bodies become hard and brittle. They may be softened by steeping them in a dilute solution of caustic potash (*liquor potassæ*), which may be obtained from a chemist.

Instruments for dissecting may be purchased from almost any firm of opticians, but the simple ones required by the beginner may be easily made at home, with the exception of a pair of tweezers which must be purchased (Fig. 18). It is only waste of money for us to purchase an expensive outfit of "tools" before we see if we like dissecting work; because, as I have already mentioned, it requires a good deal of patience and perseverance.

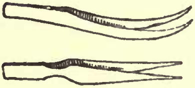


FIG. 18.—Two kinds of tweezers.

For simple dissections we shall require three dipping-tubes, somewhat similar to those used in collecting objects (Fig. 19). These may be made by obtaining some glass tubing from a chemist. The first is simply a length of about six inches, and may be cut to size by filing a groove around the tubing with a nail file. On giving the tubing a sharp blow the required length will break off. The second is made by heating the centre of a length of tubing until it becomes soft. Take a firm hold of

FIG. 19.—Glass tubes.

both ends and draw them out, allow the tube to cool, file around the centre as in the previous case, and break off. The third tube is made similarly to the second, except that while hot, and after being drawn out, the tube is bent to the required curvature.

Three needles should now be mounted in wooden handles — ordinary sewing needles pushed into wooden penholders will do very well (Fig. 20). The first should be left straight, the second bent in a flame to a right angle, the third curved to a similar shape to the third dipping-tube. The joint where the needles enter the handle may be bound round with thread, and the whole varnished over with shellac.

FIG. 20. — Dissecting needles.

With this modest equipment, a pair of sharp nail scissors, and a good penknife sharpened and ground to a razor-like edge, we can find sufficient work before us to employ all the spare hours of many a winter's night.

# CHAPTER IV.

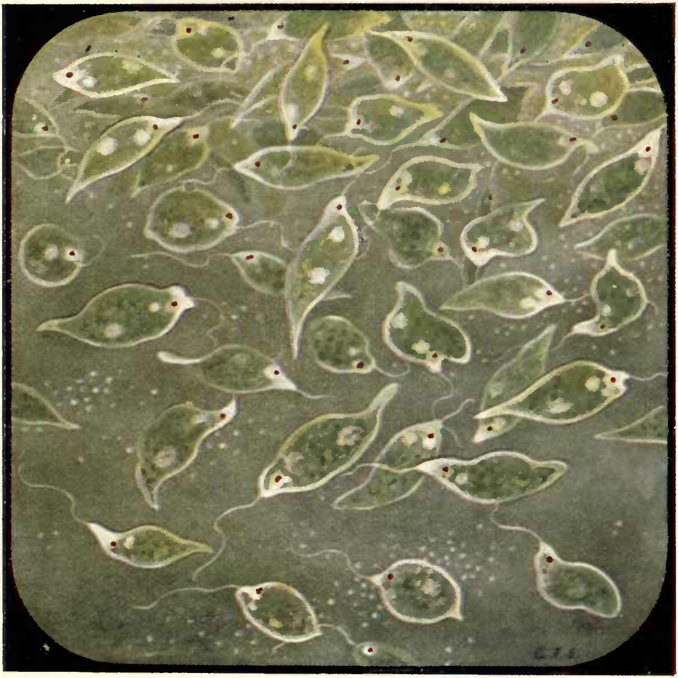
## MICROSCOPIC PLANTS.

### I.

IN almost any pond will be seen an abundant supply of minute life, both plants and animals. In some ponds, especially those in which the water is green and stagnant, life abounds in every drop of water. Each object examined under the microscope will afford us a fund of knowledge. Even from the lowliest forms of pond life we can learn a great deal which will help us when we come to study the higher and more complicated forms of vegetable and animal life.

Microscopic objects may be found either floating on the surface or swimming in the water, while a large number are to be found only at the bottom of the pond, embedded in the sand or mud. We have already seen how to collect such objects, and we will assume that we have paid a visit to a suitable pond and returned with a good "bag"—or rather, in this case, a full bottle. After allowing the water to stand a short time and the contents to settle, we may commence to examine it, taking up a little at a time in the pipette or dipping-tube—already described—and placing it in the live box. An

PLATE IX



From a water-colour drawing by] [G. Fisher-Jones

A swarm of *Euglena viridis* near the surface of a stagnant pond

easy way to quickly examine a quantity of water is to employ one of the small syringes used in filling fountain pens.

One of the first things we are sure to see are bright green objects of various shapes. These are called desmids, and they are well-known microscopic plants. When plants are mentioned some people at once think of the flowering plants in our gardens, or the plants which we have in pots and vases in our homes. These kinds of plants form only a small proportion of the plant life of the world, however, for there are many other specimens of plants of the existence of which most people are quite ignorant. Some of these plants are to be found in the most unlikely places. Would you ever think, for instance, of expecting to find interesting forms of plant life in a rotting wooden fence or an old tree trunk? Yet it is probably no exaggeration to say that in such a place it is possible to find more varieties of microscopic plant life than there are examples of the higher orders in the Botanical Gardens at Kew.

## II.

The Desmids are an extensive family of plants composed only of a single cell. They are placed at the bottom rung of the ladder of botanical classification. Desmids live in fresh water; in some ponds they are so numerous as to cause the water to assume a decided greenish colour.

In addition to presenting a very beautiful appearance the presence of this bright green colour is useful to the microscopist, for it enables the desmids to be rapidly distinguished from most other one-celled plants. The green colouring matter in desmids, and in all other plants also, is called chlorophyll. This name comes from the Greek word *chloros*, meaning "green," and by the presence of chlorophyll members of the vegetable kingdom are easily distinguished. How important this aid is we shall see later, for it is sometimes almost impossible to say whether a minute object is a vegetable or an animal from its shape alone.

Desmids are found in all manner of shapes, and there are so many varieties of them that they have been divided into groups to help in their identification. They present so many interesting problems, indeed, that books have been written on them alone.

Some desmids are more or less irregular in form, like *Euastrum*, which consists of two main portions of a bright green colour, joined together by a narrow waist-like piece. Its edges are notched and indented, and it is covered with dark green spots (*d*, Plate II.). Another variety is the crescent-shaped *Closterium*, of which there are several species, although all are of the same general shape (*b*, Plate II.). Sometimes the green cells are surrounded by a transparent substance like gelatine; occasionally this is so indistinct as to be almost invisible.

Often several of these minute plants are found joined together, forming what looks something like part of a bamboo cane with notched edges (*c*, Plate II.). This type is called *Desmidium*, and from it the desmids take their name. The variety called *Scenedesmus* also consists of several cells joined together, the last two cells having hair-like projections (*f*, Plate II.). Another desmid of a somewhat similar kind is *Pediastrum;* here the cells unite and form a rounded mass. Each cell has projections, and the whole colony presents a beautiful appearance (*e*, Plate II.).

A peculiar feature of the desmids is their constant movement through the water in which they live. How this movement is accomplished is as yet undecided. It may be that each cell has a large number of very fine hair-like organs which, like the oars of a boat, row the plant along, as is known in the case of some other minute plants which we shall consider later. Or perhaps the explanation is to be found in the fact that the cells give off some sort of exudation or discharge, and that this act causes them to move through the water.

When a desmid is fully grown it breaks up into two portions, and these commence to grow; later they themselves divide. It is in this way that these minute plants multiply. They illustrate for us the simplest mode of reproduction in Nature, that of cell-division. Often we may watch this division taking place, or see different desmids in various stages of breaking up.

Take, for instance, *Closterium*, several specimens of which we are almost sure to find in a bottleful of water from some pond. Here is a young plant exhibiting a peculiar marking like a faint belt across its centre (*a*, Fig. 21). As the tiny desmid grows this marking becomes more and more pronounced and soon becomes a notch, or "waist," so that it would seem almost as though some one had tied an invisible rope around the centre and that this rope is being drawn tighter and tighter as time goes on (*b*, Fig. 21). The waist becomes narrower and narrower until at last the plant divides completely in half and we find we have two new speci-

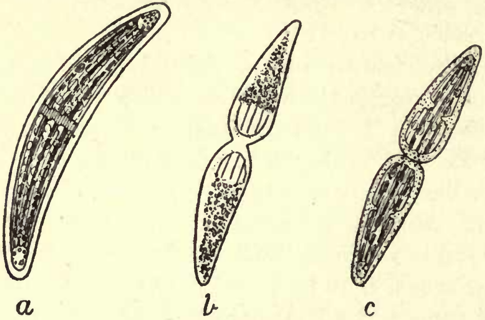



FIG. 21.—*Closterium*, a microscopic plant. (*a*) Natural view. (*b*) Dividing. (*c*) Two plants.

mens of *Closterium* (*c*, Fig. 21). If we examine the two halves carefully we can already see signs of the formation of another waist-belt, ready for the time when the two halves will themselves again divide.

## III.

Another family of one-celled plants is the Diatoms. They are even more numerous and more common than the desmids, which they resemble in many ways. There is, however, one great difference. When a desmid dies its substance becomes decomposed and perishes. On the other hand, a diatom is almost indestructible, for it is surrounded by a hard, flinty shell. This shell, or outer skeleton as it is sometimes called, is constructed of silica, extracted by the diatom from the water in which it lives. Thus, though we are able only to examine


From a water-colour drawing by] [G. Fisher-Jones

1. *Melicerta ringens.* 2. *Rotifer vulgaris.* 3. *Paramæcium aurelia.*
4. A very young *Melicerta* which has been placed a second time in water coloured by carmine.

living—or very recently dead—desmids, it is possible to examine the shell-cases of diatoms, the owners of which have been dead some time. In fact, so successfully do they resist the ravages of time and of the elements that the skeletons of diatoms which lived thousands of years ago are still perfectly preserved in some of the rocks of the Earth.

The first known forms of diatoms were discovered towards the close of the eighteenth century by Müller. In 1824 Agardh published his book, *Systema algarum*, describing nine varieties of diatoms. Now over 10,000 species are known, and about 1,200 of these are found in the fresh waters and around the coasts of Great Britain and Ireland.

Diatoms are found everywhere in all the known waters of the Earth. We may safely say that, wherever there is moisture and light, there too will diatoms be found—in ditches, ponds, and in mountain tarns; on moist rocks, and as a deposit of brownish mud in streams and pools. They live in countless millions in our oceans, and in some estuaries they are so abundant that they play an important part in diminishing the depths of channels. In some cases they have been known even to block up harbours.

In the microscope a diatom looks like a fragment of a beautifully engraved diamond, and no one can see these objects without an expression of wonder at their delicate beauty. Diatoms are of all imaginable shapes and, unlike the bright green desmids, are of a golden-brown colour. Some are disc-shaped, like *Craspedodiscus*, which is beautifully marked (*a*, Plate III.). Others resemble squares joined together, like *Melosira*. Some, again, are triangular, like *Triceratium* (*b*, Plate IV.). Perhaps the commonest variety is the oval or boat-shaped diatom, of which *Pinnularia* and *Navicula* are examples (Plate V.).

Diatoms are of all sizes, a " giant " measuring as much as $\frac{1}{50}$ inch in length; but the majority are less than $\frac{1}{1000}$ inch in size. Their shells are often of most exquisite design, and are covered with delicate markings, and minute holes or pores. The fine lines of the diatoms will illustrate for us the power of a microscope. If we were to draw two lines very carefully only $\frac{1}{100}$ inch apart, the space between them would only just be visible as a white line. To represent the lines on some diatoms we should have to divide this space of $\frac{1}{100}$ inch into over 500 spaces. The lines on some diatoms are even finer, and to represent them correctly the $\frac{1}{100}$ inch space would require to be divided into over 900 spaces! These lines are often used as objects with which to test the power and quality of microscopic objectives.

The markings on diatom shells have been the subject of endless discussion. The most expert workers and the finest lenses have been employed in the endeavour to find out what exactly is the meaning of the numerous lines and pores with which diatoms are covered. So fascinating is their study, indeed, that some scientists have been influenced to put aside all other microscopical work in order that the whole of their time might be devoted to diatoms. Because of this, and because these scientists so often talk and write about these beautiful little creatures, they have sometimes been called "diatomaniacs" by rude and ignorant people who do not understand these things.

Diatoms derive their name from two Greek words, *dia*, "across," and *tome*, "cut," because each shell is cut or divided into two parts, called the *frustules*. One of these *frustules* overlaps the other, fitting on it like the lid of a pill-box.

Like the desmids, diatoms reproduce themselves by simple cell-division, a single diatom dividing into two. So quickly can they multiply in this way that it has been calculated over 1,000,000,000 diatoms may be produced from a single parent in a month, under favourable conditions.

When a diatom dies its shell sinks through the water and falls to the bottom of the pond or ocean. So numerous do these shell-cases or skeletons become that they form a kind of mud or sediment, called diatomaceous ooze. Deep-sea soundings have shown that some of these deposits are of very great extent. Off the shores of Victoria Land, for instance, in 70° south latitude, at a depth of between 200 and 400 feet, is a deposit of mud. This extends not less than 400 miles in length and 120 miles in breadth, and is chiefly composed of the shell-cases of diatoms. In the course of ages—thousands upon thousands of years, perhaps—this mud may be hardened into a solid rock, which may be lifted above the ocean by movement of the Earth's crust. This is actually what has happened in the case of some rocks which are found to-day high and dry above the ocean in many parts of the world.

In Bohemia, rocks composed of the fossil shells of diatoms which lived years ago are found in beds which are fourteen feet thick. More wonderful still are the deposits at Richmond, Virginia, U.S.A. They are remarkable both on account of their extent and because of the number and beauty of the specimens of diatoms they contain. Here the skeletons of long-dead diatoms form a bed extending over many miles, and at some places the rock is at least forty feet in thickness. It is impossible for us to imagine the number of minute diatom shells required to form a deposit so great. We may obtain some idea of the immense numbers from particulars of a block of diatom deposit to be seen in the botanical section of the British Museum. This block measures only two cubic feet in bulk, and was obtained from a fresh-water lake in Australia. It is estimated that it contains more than twelve billions of fossil diatoms!

## IV.

One of the most beautiful objects found in pond water is *Volvox globator*. Through the microscope *Volvox* resembles a beautiful lace-like tracery, more delicate than a spider's web (see *Frontispiece*). This covering is studded with minute green spots, each of which terminates in two long cilia, or gossamer-like hairs. It is believed that it is by the aid of these cilia that *Volvox* is able to swim, for they are constantly in movement, thrashing the water. Healthy specimens are always in motion, gliding gracefully along, and resembling at times minute revolving worlds. It was this extraordinary power of moving from place to place which at


From a water-colour drawing by] [G. Fisher-Jones

1. *Stentor Roeselii* (Trumpet animalculæ). 2. *Stentor*, unattached, moving rapidly through the water. 3. Portion of a twig covered with a colony of *Stentors*. 4. *Vorticella nebulifera*. 5. *Carchesium polypinum*, an aborescent *vorticella*. 6. *Vorticella*, (*a*) self division proceeding; (*b*) an individual about to detach itself. 7. *Vorticella* detached and freely swimming.

one time led microscopists to think that *Volvox* was an animal, and controversy raged over the question for a long time. *Volvox* was first classified in the animal kingdom, but at last it was definitely described as being a true plant.

The green spots, already referred to, give *Volvox* the appearance of a minute knitted ball of orange-tinted green silk, and very exquisite it looks. It is possible to see through the outer lace-like sphere, and often smaller green globes are visible within the network. These tiny globes are really young *Volvoces*. Sometimes they are six or eight in number, but in some cases as many as twenty have been counted. Occasionally even a third generation may be seen inside the young *Volvoces* themselves.

As time goes on, the young *Volvoces* develop until there comes a day when they are sufficiently grown to shift for themselves. They break through the sphere in which they were born, the sides of their mother opening to allow them to glide through. At first they are attached to their parent by long filaments, but they soon tire of being tied by these "apron-strings." They break away, commence life on their own account, and soon grow to the size of the parent *Volvox*.

*Volvox* is not a single cell, like the desmids and diatoms, although it is included in the same botanical classification. It really belongs to a higher organization, being a colony or assemblage of minute cells, just as a daisy is a composite flower. It is to be found in those clear, fresh-water pools which are open to sunlight, for like most plants it is fond of sunshine. The water of some ponds is so full of *Volvoces* that when held up to the light in a glass jar it seems to be of a semi-transparent green colour.

*Volvox* measures from about $\frac{1}{60}$ to $\frac{1}{30}$ inch in size. The larger specimens may be seen easily with the naked eye, looking like minute specks of green matter. Because of its incessant movement, already mentioned, *Volvox* is often a difficult object to photograph or draw correctly in detail (Plate VIII.).

## V.

In pond water we often find, in addition to desmids and diatoms, several other forms of vegetable life. Sometimes we may come across long, green filaments of a variety of forms. These are the fronds of *confervæ*, and they are composed of a number of cells growing together and looking somewhat like a bamboo cane. As in the case of the desmids and other plants, they too owe their green colour to the chlorophyll they contain. In some species, as in *Zygnema*, the chlorophyll is found formed in spirals (Fig. 22).

Often two specimens of these plants may be seen to join or fuse together and the contents of one are transferred to the other, bead-like objects—called spores—being formed (*b*, Fig. 22). Spores are the first stage in the life-history of the lower plants—such as seaweed, fungi, mosses, and ferns. Just as flowering plants grow from seeds, so do the lower plants spring from spores. Perhaps the most familiar spores are the masses of brown powder on the under-side of the frond of a fern. Spores are very minute, and when ripe are scattered by the wind or water. The spores of some fungi and seaweeds disperse themselves by being able to swim in the water, and afford examples of free movement in the plant world. Because of this resemblance to animals—

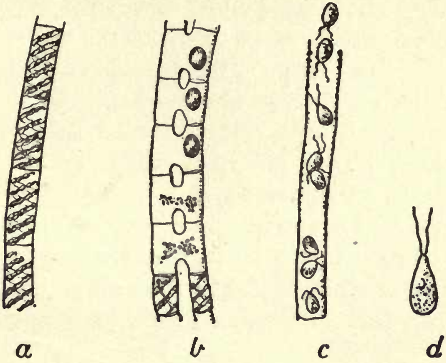


FIG. 22.—*Zygnema*, a microscopic plant. (*a*) Showing the chlorophyll spirals. (*b*) Formation of spores. (*c*) Zoospores leaving the plant. (*d*) A zoospore, showing cilia.

their being able to move about—these spores are called *zoospores*.

In the case of *Zygnema*, which we have already mentioned, zoospores are sometimes formed instead of the ordinary spores. When this occurs, the contents of the cells draw together and form the zoospores (*c*, Fig. 22), which then break away from the parent cell and move rapidly about through the water in all directions, by means of cilia, or fine hair-like appendages.

Occasionally zoospores gather together and move rapidly about in a sphere. A common example of this class of object is *Pandorina Morum* (Fig. 23), each spore in the colony of which possesses two cilia.

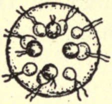


FIG. 23.—*Pandorina Morum.*

Sometimes in our examination of pond water we come across a queer-looking object, called *Euglena viridis* (Plate IX.). In some ponds they exist in such large numbers as to make the water look like pea-soup. The appearance of this minute plant in the microscope is remarkable, for it resembles nothing so much as a sole or similar fish. It is of a green colour, with a red spot, which we may imagine to be its eye, at one end and a kind of drawn-out tail at the other. Its appearance is deceptive, and it may easily be mistaken for a member of the animal kingdom, although it is really a plant with extraordinary powers of locomotion, like *Volvox* or *Pandorina Morum.*

PLATE XII

From a water-colour drawing by] [G. Fisher-Jones

*Stephanoceros Eichornii*

31

## CHAPTER V.

## MICROSCOPIC ANIMALS.

### I.

IF I were to ask if you could always distinguish between an animal and a vegetable, you would possibly think that I did not give you credit for possessing much intelligence. It is true that when we have in mind some of the more highly developed members of either kingdom, say a cat and a cabbage, the difference is very pronounced. But among the more lowly members of these kingdoms, members which interest us more at present because they are to be seen in detail only with a microscope, the difference is not so apparent. For instance, could you tell me—without referring to books—whether a sponge is of an animal or a vegetable nature? As a matter of fact, it represents a colony of animals which are more highly developed than many animals having bodies with heads, mouths, and tails, and which are not—as the sponge generally is—fastened to a rock, but swim freely about in the waters of the ocean. Appearances are deceptive, however, for many vegetable organisms seem to bear a closer resemblance to animals than does a sponge.

The problem of deciding whether certain microscopic organisms belong to the animal or the vegetable kingdom has occupied the attention of some of our most distinguished scientists, and given rise to endless discussions. At one time it was thought that we could be guided in deciding if an organism was an animal or a vegetable by the green colouring matter called chlorophyll, the presence of which was believed to indicate that an organism was certainly a true plant. Distinction by these means became difficult, however, when later on it was found that chlorophyll existed in some of the minute forms of animal life, called animalcules. On the other hand, it was found that the substance called cellulose, of which the walls of plant cells are composed, enters into the composition of certain animalcules found in the sea.

Nor are we helped in distinguishing between plants and animals according to whether or not the organism has powers of locomotion. We generally imagine an animal as being able to move from place to place, and a plant as being permanently stationary. As we have already seen, however, the plant *Volvox* is provided with organs which enable it to move about. On the other hand, there are forms of animals which are always fixed to one place. To add to the uncertainty, some organisms seem almost to have an animal form of existence at one period of their life-history, and a vegetable form at another. A well-known instance of this is the yellow fungus which is found in tan-pits, called *Æthalium*, or "flowers of tan." Not only does it move about from place to place, but it also actually feeds upon solids.

One of the most certain methods of distinguishing between one-celled plants and one-celled animals is the difference in the method of obtaining food or nutrition, as it is called. A green plant is able to live independently of other organisms, by the help of light, heat, and moisture. It builds up its substance from simple gases contained in the air and from solutions of inorganic salts, found in the soil or water. On the other hand, an animal can live practically independently of sunlight, but it cannot exist apart from other living organisms, for it depends upon them for its sustenance. It is unable to build up its structure from simple chemical constituents, as a plant does, but must be supplied with ready-made proteids. By remembering these facts we are sometimes able to say to which kingdom some microscopic form of life belongs, when otherwise we might have to admit a doubt.

From what I have just said you will easily understand that it has become very clear that the distinction between some of the simplest forms of plant and animal life is occasionally so obscure and indefinite that it does seem as though no definite dividing line can be drawn between the two kingdoms. It seems probable, indeed, that the two kingdoms do actually merge into each other by imperceptible degrees.

## II.

Wherever we find one-celled plants we may be almost certain to find also animals to feed upon them. Just as there are one-celled plants at the bottom of the ladder of botanical classification, so, too, there are one-celled animals which occupy a similar position in the classification of their kingdom. They belong to a class called the *Protozoa*, from the Greek word *proton*, "first," and *zoon*, "living thing." They are among the lowest forms of animal life. Each is composed of a single cell of living matter, a minute speck of jelly-like substance, without limbs of any sort. Each cell is complete in

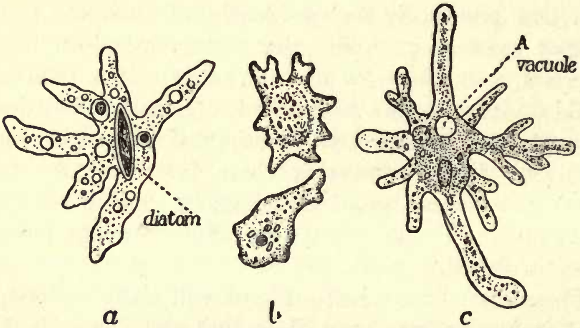


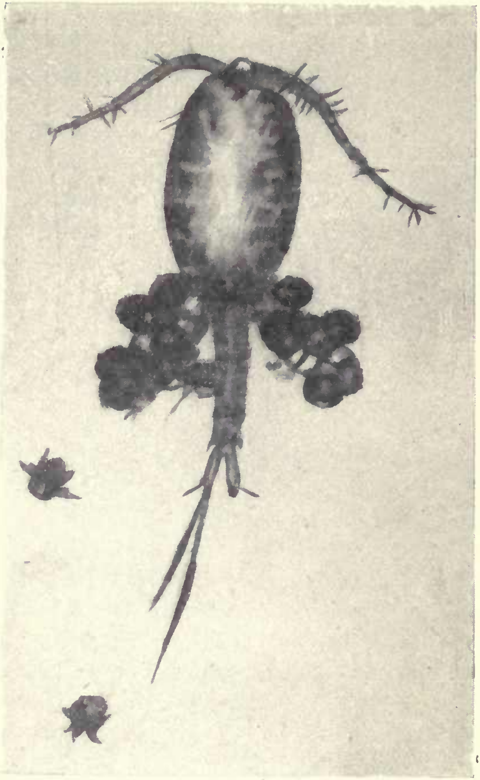

FIG. 24.—*Amœba.* (*a*) and (*c*) Showing nuclei, vacuoles and pseudopodia. (*b*) Formation of two amœbæ.

itself, however, and can move, feed, breathe, and reproduce others of its kind.

One of the best known is the *Amœba*, found both in fresh and in salt water, but more often in the sediment of ponds and rivers (Fig. 24). *Amœba* looks like a speck of jelly, for it is almost transparent. Sometimes it seems to be merged in the water in which it floats, so that it is difficult to say where the little creature begins or ends. The animalcule may be actually under the microscope, and yet the observer may not be aware of

PLATE XIII

(a)



From photo-micrographs by] [Messrs. Pathé Frères

(b) (c)

*DAPHNIA PULEX*, (a) female, (b) male; AND (c) *CYCLOPS* WITH YOUNG HATCHING OUT

it. If the insignificant speck be watched, however, it will be found to move about and constantly change in appearance, assuming some of the most grotesque forms and fantastic shapes. These changes have become so well known that when masses of cells of higher animals exhibit similar variations of form they are called *amœboids*. Among the *amœboids* are the *leucocytes*, or white corpuscles of the human blood.

It is because the *Amœba* changes its shape so often and assumes so many varieties of form that it was named *Proteus animalcule* by Rozel von Rosenhof, who discovered it in 1755. In Greek mythology, Proteus was an "old man of the sea," who looked after the seal flocks of Neptune. He had a great reputation as a prophet, and possessed the gift of endless transformation, adopting all manner of shapes and disguises in order to escape from those inquiring people who wished to make him prophesy for them. The name *Proteus animalcule* was changed to *Amibe* by Bury St. Vincent; and the present name, *Amœba*, is the corresponding name in Greek, and means "change."

Towards the centre of the *Amœba* is a nucleus, filled with granular particles, and often showing one or more bubble-like objects, called the *vacuoles*. Although this nucleus does not, as a rule, alter in appearance, it moves with every change of shape in the *Amœba* (*c*, Fig. 24). *Amœba* reproduces itself by division, one cell dividing into two (*b*, Fig. 24). Before this division takes place, however, the nucleus splits up into two portions, each of which contains half the parent nucleus. In some cases it takes only fifteen minutes for this to be accomplished, and it is thus possible to watch the entire process in the microscope.

*Amœbæ* move about in a curious way, for they are not provided with limbs, and have therefore to press themselves along. This they do by putting forth *pseudopodia*, a word derived from the Greek *pseudos*, " false," and *pous*, " foot." A protrusion, like a minute finger, is first pushed out from some part of the body of the *Amœba*. Substance from the body is then transferred to it. As soon as the transfer is completed, another protrusion is put out, and the *Amœba* is thus able to draw its body forward or backward, moving in any direction.

As it moves thus from place to place the tiny creature picks up its food, encountering small particles of vegetable matter, or occasionally a diatom. These enter through any part of its body and mix with its substance (*a*, Fig. 24).

*Amœba* may rightly be counted among our most wonderful animals, for, as Professor Huxley has said, it walks without legs, eats without a mouth, and digests without a stomach !

## III.

Some animalcules exist in many kinds of vegetable infusions, and are therefore called infusory animalcules. The great microscopist, Ehrenberg, divided them all into two kinds: *Polygastric* (" many-stomached ") and *Rotiferous*.

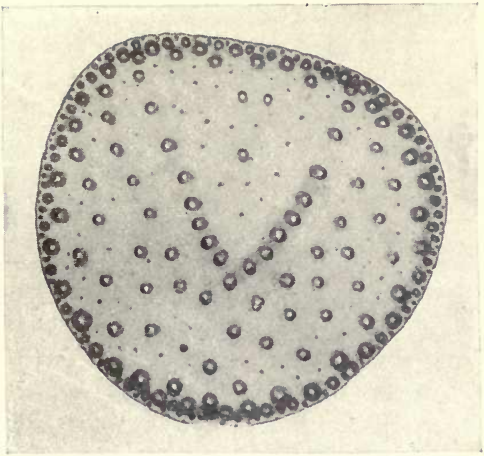
Of the *Polygastrica* a typical example is the beautiful *Paramœcium Aurelia*, which moves through the water in constant search for its prey (3, Plate X.). It is strange that this magnificent animalcule should be found in the dirtiest and filthiest of ponds, but it is a fact that it loves best the kind of pond which is a receptacle for the bodies of dead cats and dogs. Here it does great work in clearing away the filth and refuse, and so prevents it destroying the life of higher animals and human beings. *Paramœcium* is of an oblong shape and covered all over with cilia. It is very active indeed, darting rapidly backward and forward, here and there, or suddenly turning round and, by a quick movement, changing direction altogether. In its inside we can see several spots, and an interesting experiment may be performed. If we mix a little colouring matter, say carmine or indigo, with the water in which *Paramœcium* is confined, we shall soon see that the spots in its inside become similarly coloured. This is due to the animalcule taking in the coloured water, and its inside becoming stained with it. From this experiment Ehrenberg came to the conclusion that the spots were stomachs; and as similar spots are very common amongst these animalcules, that is the reason he called the species "the many-stomached." It is now thought, however, that these spots are not true stomachs, but spaces, or vacuoles, in the animalcule's body.

The second kind of infusory animalcule, the *Rotifera*, are so called because with the microscope they appear to have little wheels on the upper part of their bodies. Their name comes from the Latin *rota*, "a wheel," and *fero*, "I bear." For this reason they are sometimes called "wheel animalcules." The so-called wheels are really two extended portions of the animalcule's body, the edges of which are covered with a large number of cilia. These cilia are moving incessantly, and thus cause the impression of a tiny wheel rotating on an axis.

One of the commonest wheel animalcules is *Rotifer vulgaris*, found on the leaves and stems of almost any common water plant (2, Plate X.). A more interesting member of the family is *Melicerta*, the brick-building *Rotifer* (1, Plate X.). It is also found on water plants, and to the unaided eye looks like a little twig or stump about $\frac{1}{30}$ inch in length, fixed to the plant stem by one end of its body. In the microscope, the little stump is seen to consist of numbers of rounded pellets like minute bricks, and placed in regular rows one above the other. As we watch the little tube of bricks, we are sure to see before very long the head of *Melicerta* peep cautiously above the edge. Suddenly, as though assured that the coast is clear, *Melicerta* fearlessly thrusts out its head, which then expands and looks not unlike a minute silver pansy. The edges of the petal-like lobes of the head are surrounded with innumerable cilia, always in rhythmical motion. When watching it under the microscope, it is most difficult to believe that the lobes are not actually two minute toothed cog-wheels, rapidly rotating.

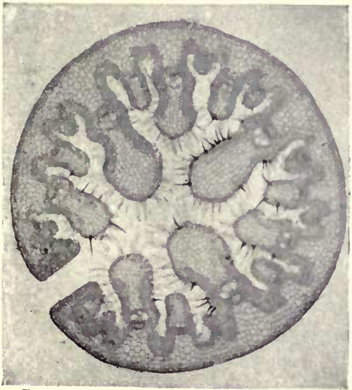
On further study, *Melicerta* is seen to be composed of transparent, fleshy matter with many folds. At one side is a pair of hooked spines, while at the other are two slender projections. Below the four petal-like lobes is a kind of chin, immediately beneath which is the apparatus with which *Melicerta* makes the bricks for its

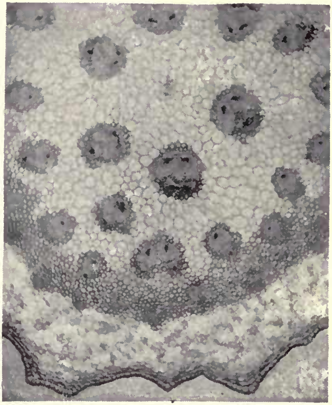
PLATE XIV



From a photo-micrograph by] [A. E. Smith

(a)





From photo-micrographs by] [E. Cuzner, F.R.M.S.

(b) (c)

SECTIONS OF PLANTS

(a) Rattan cane. (b) Stem of Ruscus. (c) Marram grass

"house." The material for the bricks consists of matter gathered from the surrounding water and brought within reach of the brick-making apparatus in currents set up in the water by the vibrating cilia. The particles so gathered may be seen whirling around the petal-like lobes in the currents they set up. They are passed down narrow grooves on each side of the chin, already referred to, until they reach the brick-making apparatus. This is in the form of a minute hemispherical cup, which acts as both mixing chamber and mould. The particles are here welded together and form a tiny brick, which is then placed on the rim of the tower by *Melicerta* bending forward its head and depositing the brick there. Brick after brick is thus placed in position, and the tower rapidly increases in height.

An interesting and beautiful experiment may be performed with *Melicerta* by adding to the water in which it is working a little carmine colouring matter. This is taken in with the particles, and the resulting brick is of a red colour. The colouring matter in the water may be changed at will, and it is thus possible to cause *Melicerta* to build a tower of different coloured bands, the width of each band depending on the length of time during which *Melicerta* is allowed to work in the water containing any particular colouring (4, Plate X.).

## IV.

If some hay be steeped in a glass of water for a few days, a number of beautiful little animalcules, called *Vorticellæ*, will be almost certain to appear. Some are large enough to be seen with the unaided eye, but others can only be examined with the microscope. You may easily distinguish *Vorticellæ,* because they have tiny, cup-shaped bodies on a long stalk, and look more like a cluster of beautiful microscopic lilies-of-the-valley than a group of minute animals. If the slide on which they are placed be jarred, or if the little creatures be otherwise disturbed, the stalk contracts into a spiral, drawing the cup-shaped body down to its base (4, Plate XI.).

*Vorticellæ* draw their food into their mouths by setting up currents in the water. These currents are caused by the constant movements of the cilia, with which the mouth of the tiny cup is surrounded. The currents of water pass into the body of the animalcule by means of a minute aperture, and pass out again by a similar but different aperture. Many interesting changes may be noticed in the *Vorticellæ,* which sometimes become detached from their stalks, the cup-like body rolling about free in the water with contracted mouth (7, Plate XI.).

Another common and well-known infusory animalcule is *Stentor,* the "Trumpet-animalcule," found attached to the under-side of duckweed in fresh water (1, Plate XI.). It is generally of a brilliant green colour, and is comparatively large. When fully extended it may measure $\frac{1}{25}$ inch in length. In appearance it resembles the mouth of a cornet, or bugle, and is a very beautiful object. Its wide, trumpet-like mouth is fringed with long cilia. It reproduces by dividing into two.

## V.

Another interesting *Rotifer* which, like *Melicerta,* is also a tube-dweller, is *Stephanoceros Eichornii* (Plate XII.).

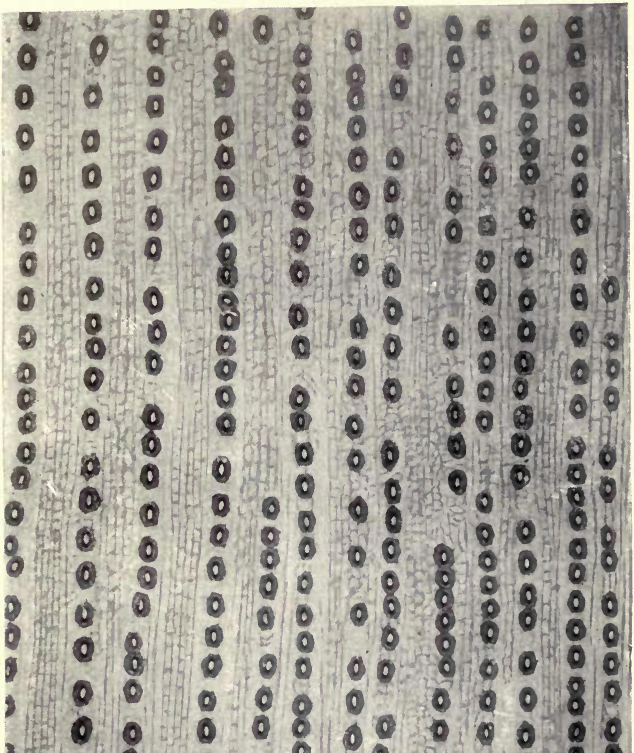
It has a transparent tube, or body, resembling gelatine, inside which may be seen differently coloured objects. Some of these are the internal organs, and others, perhaps, are animalcules which have been swallowed and upon which *Stephanoceros* feeds. Occasionally clusters of eggs may be seen, for these *Rotifers* multiply in a similar way to *Daphnias*—described in the next chapter—the eggs being hatched before leaving the body of the parent. It is most interesting to watch the development of the young *Stephanoceros*, which, from the time of its birth to full growth, occupies from five to ten days.

You will readily understand that *Stephanoceros* is an exceedingly difficult object to draw, when I tell you that most of the existing illustrations of it are incorrect. Mr. Martin Duncan, F.R.M.S., searched the library of the Zoological Society for illustrations for this book, and he believes that no good illustration exists. Some years ago Mr. Duncan succeeded in taking an instantaneous photo-micrograph of it, however, and this photograph he kindly placed at the disposal of my friend Mr. Fisher-Jones, who has made the very beautiful drawing shown in Plate X., the details of which may be taken as being substantially correct.

The magnificent appearance of *Stephanoceros* is due to the five curved arms which protrude above it, forming a figure resembling a delicate arch or dome. These curved arms may be likened to the tentacles of an octopus, for with them *Stephanoceros* catches and retains its prey. They are furnished with fifteen rows of short, vibrating cilia, and may be withdrawn into the tube at will. This generally happens if the creature receives a shock from the jarring of the microscope stage or the plant-stem to which it clings.

Unfortunately, *Stephanoceros* is not very common. It should be looked for on the under-surface of aquatic plants, such as the water-lily. Specimens once having been obtained may be kept alive in the aquarium, and under favourable circumstances will thrive and multiply. They should be kept in water obtained from the pond in which they were found.

PLATE XV



STOMATA

From a photo-micrograph by] [A. Flatters

## CHAPTER VI.

## DAPHNIA AND CYCLOPS.

### I.

ALTHOUGH the subjects of this chapter are microscopic animals and therefore, strictly speaking, should have been included in the previous chapter, I am sure you will not mind me giving them a chapter to themselves, for they are sufficiently interesting to warrant it, as I think you will agree after you have studied them. If we have spent any length of time collecting desmids and other similar objects at a pond, we cannot fail to have noticed some of the comparatively large forms of animal life there. I do not mean frogs and newts, but the microscopic crabs, or water-fleas, and that curious looking object called *Cyclops*, the one-eyed.

The celebrated Dr. Johnson once defined the word "insect" as meaning "anything small and contemptible," but this is by no means the definition of the word to-day. Science has stepped in, and an insect is now more definitely defined. At the first glance we might almost assert that the water-flea (Fig. 25) is an insect, but it is not truly so, for it does not conform to those characteristic features by which insects are recognized. Although it may seem very similar in appearance to a flea, *Daphnia pulex,* the water-flea, belongs to that class of animals called *Crustaceans.* These have their soft bodies protected by an outer crust or shell, and the crab and the lobster are larger specimens of the same order. There

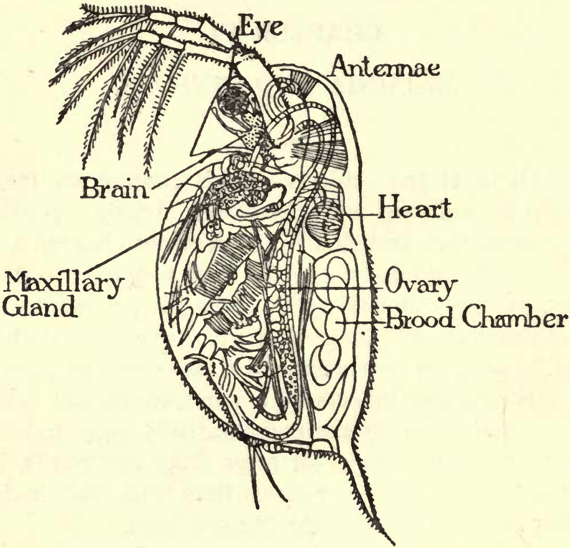



FIG. 25.—*Daphnia,* the water-flea.

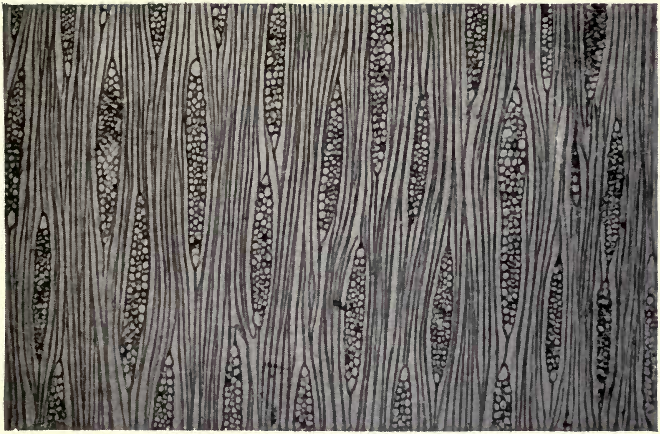
are many other members of this interesting family, some of the members of the lower orders living only as parasites. These are in many cases so different from the higher members that they do not appear to bear any resemblance to them. It is, nevertheless, a fact that whether they live on land—as do the centipedes and the multipedes—or live in water—as the water-flea and the brine-shrimps—all once belonged to the same original stock.

*Daphnia* belongs to a sub-division of *Crustacea* with the rather long name of *Entomostracans*, meaning shelled insects. This name is likely to be confusing unless we keep well before us the fact that these creatures are not truly insects. The true flea is an insect having head, thorax, and abdomen, but *Daphnia* has its head encased in a shell and has no neck; so that its head and thorax are not separate but run into one another. The difference will be clearly seen by comparing together *a* and *b*, Plate XIII., and Plate XXXIV. It does not breathe through *tracheæ* or breathing tubes, but has numerous legs with gill-like appendages. Because these leg-appendages are to *Daphnia* what lungs are to us—or gills to a fish—this tiny water-flea may be said to breathe through its toes! Water-fleas have an ancient line of ancestors, for they have been traced back to the Coal Age—that period of the Earth's history during which our coal was formed. In those far-off times water-fleas must have lived in large numbers in the great standing pools of the coal forests.

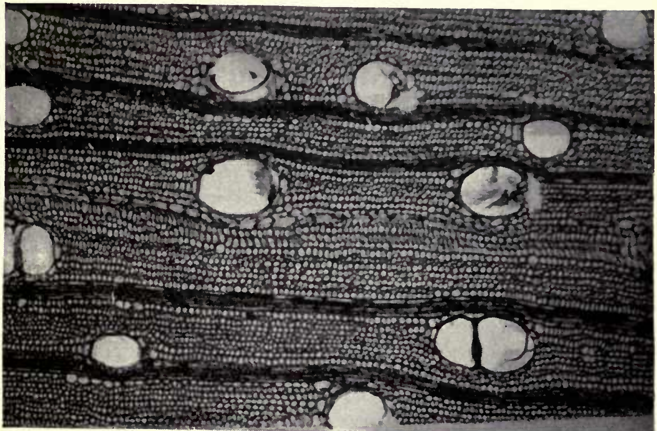
*Daphnia* has a body covered with an almost transparent casing, like that of a shrimp. Although the name of their sub-division means shelled insects, their covering cannot be truly described as a shell. It is composed of *chitine* (pronounced "ki-tin"), a name which comes from a Greek word meaning "a tunic or outer dress." Chitine is indeed a wonderful substance, for it is found in the insect world in an endless variety of forms and shapes. The hard black bodies of beetles are composed of it ; as are the downy wings of the butterfly ; the facets of insects' eyes ; the tendons, legs, hair, membranes, and many other parts of their bodies.

Through the transparent shell of the water-flea may be seen the internal organs at work. They furnish a wonderfully interesting sight, including a curious organ which pumps like a heart, and many canal-like veins and arteries. If the specimen is a female it may be possible to see also numerous eggs. If one has sufficient patience these may be watched until they hatch out.

Unlike birds, which first lay and then hatch their eggs in their nests, *Daphnia* both lays and hatches her eggs inside her body, and for this a special receptacle is provided by Nature, called the brood-pouch. Here the eggs remain until the little animals are hatched. Even then they are not cast out into the waters to fend for themselves, but are kept inside until they have grown old enough to swim about and obtain an independent livelihood. The brood-pouch is open to the surrounding water, which enters through a slit in the shell, behind the tail. The eggs are prevented from floating out before their time by a slender tongue-like projection, fixed to the back of the mother. When the young are sufficiently grown to take their place in the world their mother has only to depress her body a little more than ordinarily, and the door is open, the young sliding from the brood-pouch into the open water, like little ships just launched. As is often the case with crustaceans, the young *Daphnias* are quite unlike the parent. At first their body appears



(a)



From photo-micrographs by] (b) [C. D. Holmes

SECTIONS OF MAHOGANY

(a) Longitudinal section. (b) Transverse section

like the bowl of a miniature spoon, being transparent and ending in two points carrying many bristle-like hairs. The large dark eye can be clearly seen in front, and three pairs of swimming feet, jointed and bristled, project stiffly on either side.

The body of *Daphnia* is divided into five segments, each of which has attached to it a pair of leaf-like swimming feet. From the head there branch two pairs of plumed appendages, which are the *antennæ*. This word comes from the Latin, and means "horns or feelers." *Daphnia* has only one eye, which, looking very bright and inquisitive, is really a single cluster of *ocelli*, or insect eyes.

*Daphnias* may be found in large numbers in many pools and ditches, coming to the surface in the mornings and evenings or in cloudy weather, but seeking the depths of the water during the heat of the day. They swim by taking short springs, darting through the water in a succession of jerks, and this is another reason why they have been called water-fleas. The males are usually smaller than the females and certainly much more scarce, being rarely met with before the end of summer.

*Daphnias* have many enemies, for they are tasty food for several other inhabitants of the water in which they live. It has been said on good authority that Loch Leven trout owe their superior sweetness and richness of flavour to their food, which consists of small shell-fish and these *Entomostracea*.

II.

Another interesting species of this same order is *Cyclops* (Fig. 26). *Cyclops* is not at all particular as to whether it lives in the clearest streams or in the muddiest and most stagnant pools. It may be seen like an animated atom—it is not much more than $\frac{1}{16}$ inch in length—scuttling here and there by a rapid succession of short leaps among the water weeds. *Cyclops* has only one eye, and that is how it gets its name, for in classical mythology the Cyclops were a wild race of giants led by their one-eyed chief Polyphemus, whose single eye was placed in the middle of his forehead. You have perhaps read the story of how Ulysses was wrecked off the coast of Sicily, and confined in a cave by Polyphemus, and of how he contrived to escape by making the monster drunk and burning out his single eye—so large that it required five heroes to " grind the pupil out "—by a red-hot stake of olive wood.

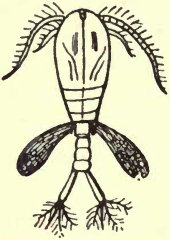


FIG. 26.—*Cyclops.*

The eye of tiny *Cyclops* is placed similarly in the middle of its forehead and glares like a minute ruby. It is so small, however, that it cannot be touched with the point of the finest needle ; it is nevertheless of very elaborate construction, consisting of a number of simple eyes.

*Cyclops* has four pairs of swimming feet, and one rudimentary pair. It also has two pairs of *antennæ*. Both feet and *antennæ* are covered at each of their many joints with tufts of feathery plumes. Its body is pearshaped, broad in front and tapering behind, and is soft and gelatinous. This body is divided into two distinct parts, the thorax and abdomen. A jointed shell forms a buckler which almost entirely encloses the head and thorax. The abdomen is slender and might be mistaken for the tiny creature's tail. The tail is at the extremity of the abdomen, however, and has numerous plume-like tufts.

On either side of the abdomen of the female is an oval bag or sac, joined to the body by a very slender thread, reminding one of John Gilpin, when, as the poem says,

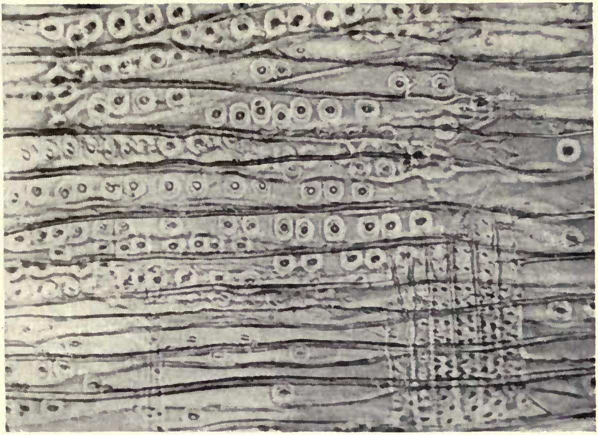
> "He hung a bottle on each side
> To keep his balance true."

These oval bags are packed very full with clear and transparent globules, which are the eggs. Not only are the eggs thus exposed to the action of the water as necessary, but they are also protected from being destroyed by the enemies of *Cyclops*. The eggs are first developed in the body of the mother, in a gland called the ovary. When they are sufficiently matured they are transferred into the oval sacs, through the exceedingly slender tube connecting them to the body. They are then carried about by the mother until they are hatched, when the young *Cyclops* emerge in dozens (*c*, Plate XIII.). The sacs, being no longer required, become detached and decay.

*Cyclops*, while not so much of an acrobat as *Daphnia*, is nevertheless a very active creature. It swims not only with its legs and tail, but also strikes the water vigorously with all its limbs and *antennæ*. By rapidly moving its feet a whirlpool is created in the surrounding water and minute animals of various kinds are thus brought to its mouth. *Cyclops* is sometimes a cannibal, however, for it has been known to devour even its own young brought in by the whirlpool.

Both *Daphnia* and *Cyclops* belong to the *Branchiopoda,* or "gill-footed" order. There are several other interesting members which you may sometimes find in ponds and streams. These include *Artemia salina,* or the brine-shrimp, found in salt marshes and in reservoirs at places such as Lymington, where brine is deposited previous to boiling. It has peculiar movements, for in addition to being able to swim in the correct position it can also swim on its back or sides by means of its tail, its feet being also in constant motion.

PLATE XVII



(a)

From photo-micrographs by] (b) [A. Flatters

LONGITUDINAL SECTIONS OF WOOD

(a) Common pine. (b) Vascular bundle of *Pteris Aquilina*

## CHAPTER VII.

## PLANT LIFE.

### I.

NO objects for microscopic examination are more easily obtained than plants. A few minutes in the fields or meadows will enable us to gather material sufficient for many hours' observations at home. The study of plant life, or Botany, is a very extensive one, and includes the study of vegetable cells and tissues. We have already seen that all living things, whether animals or plants, consist of cells, and that some consist only of a single cell, like the desmids, while others in a higher stage of development consist of a collection or assemblage of cells, joined together (see Plate XIV.), just as a house consists of a number of separate bricks cemented together with mortar. An elaborately formed tree is composed of exactly the same kind of material as the simplest plant. Those objects which consist of only a single cell are said to be unicellular, while those consisting of many cells are multicellular in composition. In studying the plant cell we are beginning at the lowest rung in the study of life itself.

Plant cells were discovered about a hundred years ago. The early workers had some peculiar theories about their behaviour. For instance, it was at one time believed that the walls of the cell were its most important part—that they were indeed the cell itself. It was also thought that the cell contents were merely food for the cell walls, and that in those cases where the cells were empty the contents had been digested or assimilated by the cell walls. Later it was discovered that the contents of the cell are actually of far greater importance than the walls, and that the cell walls did not feed on the cell contents. It was also found that the cause of some cells being empty was due to the fact that the contents of the cell had dropped out, or had been accidentally shaken out, when the specimen was being prepared for observation under the microscope.

The contents of vegetable cells was first recognized in 1835 by the French naturalist Dujardin, who described the substance as being formed of a greyish, semi-transparent material of a slimy nature. In 1846 this jelly-like substance was named "protoplasm" by the botanist Hugo von Mohl. The word protoplasm comes from the Greek *proton*, meaning "first," and *plasma*, "formed substance." Protoplasm is often stained by different coloured dyes by microscopists, for by these means it is rendered more easily visible.

## II.

If we make a section of some plant, or vegetable—by cutting off a thin slice with a razor or sharp knife—and examine it with the microscope, we see at once that it is composed of minute hollow bodies. Often their arrangement is symmetrical and very pleasing, as in the case of rattan cane (*a*, Plate XIV.) and of many flower buds. If the substance be placed in water for a few days until it becomes decomposed, these hollow bodies will separate and their different forms will then be clearly seen. They are the plant cells of which we have been speaking, and are generally of a round nature. They are also found in other forms, such as oval or star-shaped. Occasionally they lose their cell-like shape entirely and appear as spirals, and are thus difficult to recognize as cells (Fig. 27). The cells of some plants are pressed closely together, but others are loosely packed. Cells of the latter kind are to be found in most pulpy fruits.

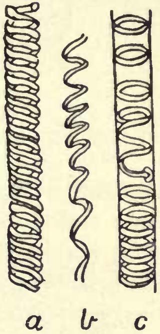


FIG. 27.—Plant vessels. (*a*) Spiral, from leaf-stalk of rhubarb. (*b*) The same, unrolled. (*c*) Ring-like, from root of wheat.

If we examine the cells of a thin section from some soft fruit like an apple, we find that in the interior of each is a central spot, or nucleus (*a*, Fig. 28). It is from these nuclei that the cells originate. New cells are born from a similar nucleus, or by the division of a thin membrane in the centre of the cell. This membrane takes the place of the nucleus and is called the "primordial cuticle." Cells thus formed are either free like those in the illustration, or are packed closely together. In the latter case they are said to form a tissue.

When a section of a fruit is made in which the cells are pressed together equally and on all sides, the cells are seen to be hexagonal in shape. Such cells may be seen in the pith of most plants and especially in the common elder (*b*, Fig. 28). Another type of cell is the stellate or star-shaped found in most water-plants, such as the com-

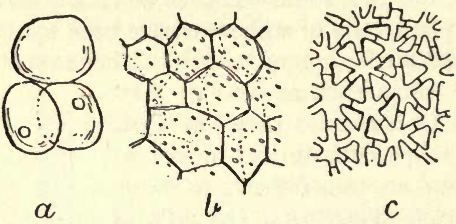


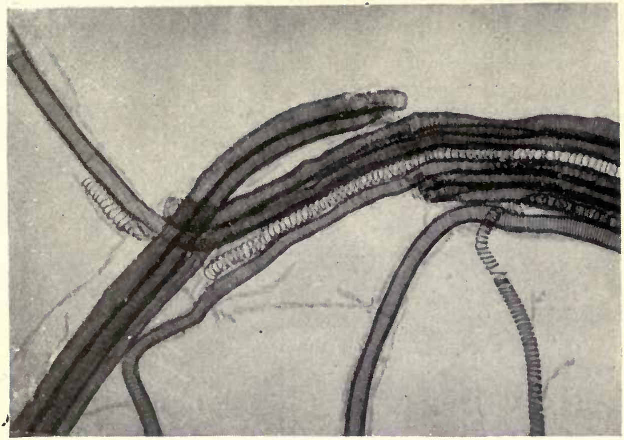

FIG. 28.—Vegetable-cells. (*a*) Apple. (*b*) Elder. (*c*) Rush.

mon rush or sedge (*c*, Fig. 28). As will at once be seen, these stellate-shaped cells allow a large quantity of air to be admitted in the spaces between the cells, and the plant is thus made more buoyant and better adapted for growth in water or marshy places.

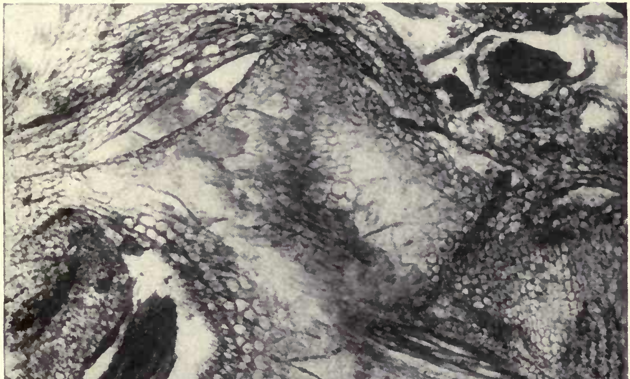
## III.

The skin or thin membrane covering our bodies and that of the bodies of animals is called the epidermis. If the leaf of any plant be examined, a similar thin layer or outer skin will be seen ; this is also called the epidermis or cuticle. It is made up of minute cells, and varies in form in different plants. Scattered over the surface of this epidermis are curious little apertures or pores. These are the *stomata*, a Latin word meaning " little mouths." Through them the plant breathes—for plants require to breathe just as animals do, though the process

PLATE XVIII



From a photo-micrograph by] (a) [C. D. Holmes



From a photo-micrograph by] (b) [A. E. Smith

(a) SPIRAL VESSELS FROM RHUBARB. (b) SECTION OF COAL, SHOWING FOSSIL ROOTS AND STEMS

is not effected by the same means. When we " breathe in " we inhale oxygen into our lungs, and when we " breathe out " we exhale carbon dioxide. Our lungs have extracted the oxygen they needed and sent back the poisonous carbon dioxide, for which they have no use. Plants are differently constituted, however, for they actually need the carbon dioxide which we cannot use. This is fortunate, as is also the fact that plants give out oxygen during the hours of daylight, for they thus help to purify the air.

The *stomata* are generally found to be minute oval openings, having at each side a crescent or kidney-shaped guard-cell which, by opening or closing, regulates the amount of air admitted to the leaf (Plate XV.). *Stomata* are well seen in the leaf of the hyacinth, for in this plant the cells of the epidermis are transparent, and the *stomata* filled with green colouring matter. *Stomata* are found to be most abundant on the lower side of leaves; indeed, on some plants they are only found there. They vary in size in different plants. In water-cress, for instance, they are very small, and the cells of the epidermis are not straight like those of the hyacinth but sinuous, winding about like a river.

Just as the *stomata* vary in size, so too do they vary in number in different plants. It has been estimated that the under-surface of leaves of the hydrangea have 160,000 *stomata* to the square inch. In leaves which float on the surface of the water the *stomata* are found on the upper surfaces only. Those leaves which live entirely submerged in water have no *stomata*.

## IV.

When cells retain their original shape the tissue they form is called "cellular." But when the cells become elongated, or unite together forming an elongated tube, the tissue thus formed is called "vascular." The interior of vascular tissue may be plain or marked by dots or pores.

In the ribs of leaves and the stems of plants elongated fibres are seen lying side by side. These may also be observed in a longitudinal section of wood (*a*, Plate XVI.). This appearance is called "ligneous or woody tissue," and of it are composed nearly all wood and the more woody parts of plants. The object of woody formation in plants is to furnish a support for the plant. When this support is once formed the cells of which it is composed do not take any further share in the growth of the plant. They do, however, help to convey fluid from the roots upwards through the stem and branches to the leaves.

Large open tubes are observed in the transverse sections of most plants which look like circular openings in the section and are called "ducts" (*b*, Plate XVI.). Those which are marked with pores—as in the case of deal, for example—are called "dotted ducts." They are formed by deposits in the interior of the tube and are found in great variety.

The cone-bearing or fir tribe of plants have a well-known marking of the vascular tissue, called "glandular woody tissue." In the case of the common pine tree, for instance, little circular discs are seen, each having a black dot in its centre (*a*, Plate XVII.). These may be observed easily by making a thin longitudinal section of a piece of wood. If a drop of water be placed on the section the circular discs will be more clearly seen.

## V.

If we bend and break the stem of a strawberry leaf we find that the two pieces are held together by a number of delicate threads of a spiral nature. These spiral vessels are found in the stems and leaves of many plants, and resemble in some cases—rhubarb, for instance—long compressed springs (*a*, Plate XVIII.). Occasionally the continuity of the spiral is broken, or even only a ring of thread remains to mark the place where the complete spiral would have been. When this is the case the ring-like vessels are called "annular." Annular vessels are easily found in the leaves of garden rhubarb, or in the roots of growing wheat (*c*, Fig. 27). Yet another form of spiral vessels is that found in the roots and stems of ferns. Here the vessel is found in a many-sided form, and because of its ladder-like appearance is known as "scalariform tissue" (*b*, Plate XVII.). Not only do the spiral cells give lightness and elasticity to a leaf or a stem, but they also act as *tracheæ* for the breathing organs, keeping the air passages open, just as the spiral wire inside a garden hose-pipe keeps it from "kinking."

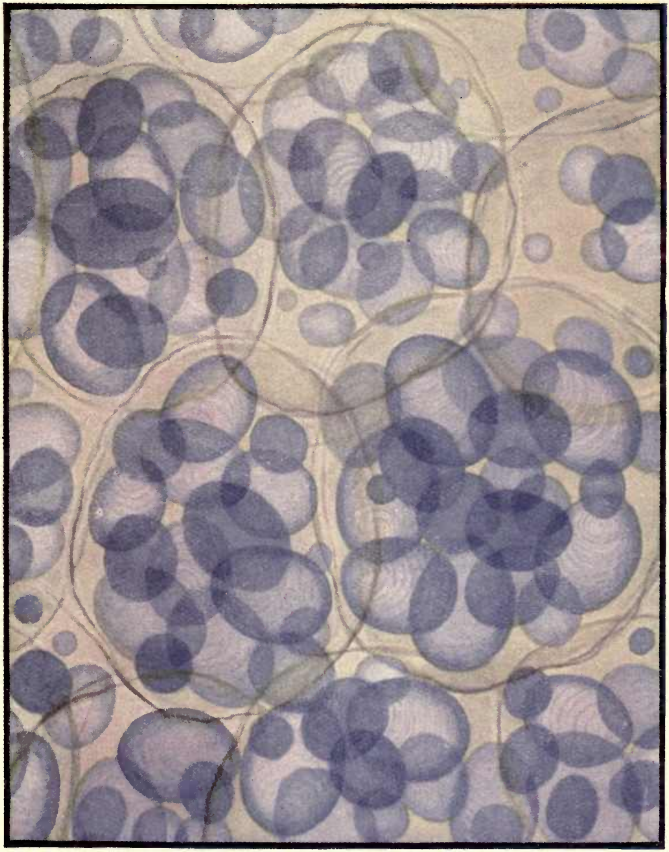
If a thin transparent section of a piece of the bark of a plant be examined under the microscope its structure may be studied. Outside is the epidermis or cuticle—corresponding to the bark of a tree—and below are two layers of cellular tissue, the innermost layer of which is clearly seen to be woody tissue. The outer cellular layer of some trees is very fully developed and is known as cork. Cork is obtained from the bark of an oak tree grown principally in the Levant and in Portugal. This cellular structure of cork may be plainly seen in a very thin section, the cells being of a square shape and often pitted.

## VI.

Ages ago, in what is called the Carboniferous period of the Earth's history, the world was in a very different state to that in which we know it to-day. The atmosphere was saturated with water vapour, the rainfall was very heavy, and the climate was a great deal warmer than at the present time. The air contained a large amount of the poisonous gas carbon dioxide, the plants and trees grew very fast, and because of the great quantities of water were soft and juicy. In this manner a sort of vast swampy jungle came into existence, perhaps not unlike the dense mangrove-swamps which now fringe the coast of Florida. Pine trees, ferns, and giant horse-tails grew alongside club mosses fifty feet in height, and six feet in diameter. These masses of vegetation lived and died and became covered with deposits of sand and mud. The pressure of these deposits became so great that the trees and leaves were pressed flat, forming layers of material several feet thick. This pressure, coupled with the internal heat of the Earth which partly baked this material, continued until in due time the trees and vegetation were transformed into coal.

Not only have we learned these facts concerning the

PLATE XIX



From a water-colour drawing by] [G. Fisher-Jones

Starch grains from a potato

origin of coal from the fossil trees and plants found in the coal measures, but we know of them also because if a thin section of coal be examined in the microscope it shows the material to be of vegetable origin. (Notice the similar appearance of *b*, Plate XVI., and *b*, Plate XVIII.)

Coal is a somewhat difficult object to examine under the microscope, and to enable us to see its construction in detail we must have a very thin section. This may be obtained by fastening a suitable piece to a glass slide with Canada balsam, and—when this has set firmly—rubbing the coal down on a fine stone, until it is thin enough to be satisfactorily examined. From such a section we find that coal shows both cellular and vascular tissue. The latter tissue is of the glandular woody variety, and from this fact we learn that the trees or plants which formed the coal belonged to the cone-bearing or fir family. This inference is fully borne out by the remains of these trees and plants which have been preserved in the coal measures.

## VII.

We have dealt with the outside forms of plant tissues, and we are now to learn something of the cell contents. Here we find veritable store chambers where may be seen secretions of starch, sugar, gum, oils, and of colouring matter. If the cells of the growing parts and roots of plants be examined under the microscope a number of round grains are to be seen. These are particularly abundant in the tubers of a potato and in wheat, corn, and other cereals. In a section of a potato the grains may be seen lying in the cells of which the potato is composed (*a*, Plate XIX.). If a solution of iodine be made up by adding five grains of *iodine* and five grains of *iodide of potassium* to an ounce of distilled water, and if a drop be applied to the potato cells, the rounded granules will at once become a beautiful deep blue in colour. This proves that they are starch, for no other substance will change to blue in this way when iodine is applied.

Granules of starch are found in some part or other of most plants, and they are of many sizes and shapes. The starch-grains of wheat are rounded and of different sizes (*b*, Plate XIX.). Those of the oat may be recognized by the fact that the small granules stick together in globular forms, which when broken up give place to very irregular grains (*c*, Plate XIX.). The largest known starch-grains are those of arrowroot called *Tous-les-Mois* (*a*, Plate XIX.). As in the case of the starch-grains of the potato, these grains look as though they consisted of numbers of plates, laid one upon the other, and decreasing in size towards the top. Often a small black irregular spot is seen towards the centre of the grains. The starch of Indian corn has a peculiar marking like a dark cross at the centre of each grain (*b*, Plate XIX.). Sago and tapioca are good objects for examination, as they consist almost entirely of starch (*c*, Plate XIX.).

Often in examining leaves and stems with the microscope we come across numbers of minute objects embedded in the plant. They are found in the cell cavities of many plants, and also may be seen in the white milky juice from the dandelion and in the juice of the common hyacinth. These are raphides, a name derived from the

Greek word *raphis*, meaning "a needle." Indeed the raphides do look like bundles of minute needles, lying side by side (*a*, Fig. 29). They vary in size from $\frac{1}{40}$ to $\frac{1}{1000}$ inch, and are really deposits of insoluble salts in the fluids of the plant.

Rhubarb raphides consist of oxalate of lime, a mineral found in many other plants (*c*, Fig. 29). Raphides are most abundant in rhubarb, especially in Turkey or Russian rhubarb, and sometimes they are so numerous that if the root be chewed it seems quite gritty. Raphides

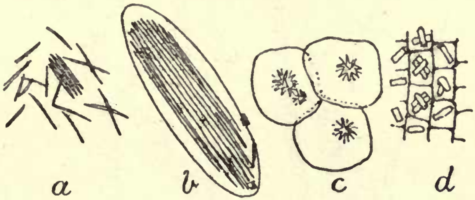



FIG. 29.—*Raphides.* (*a*) From hyacinth. (*b*) Bundle contained in a cell from leaf of aloe. (*c*) From stalk of rhubarb. (*d*) From outer coat of an onion.

are also found abundantly in the bulbs of the hyacinth (*a*, Fig. 29), tulip and onion (*d*, Fig. 29), and in the apple-tree, lime, ash, elm; in the husks of rice, wheat, and in other grains. Sometimes they occur in all parts of the plant—in the wood, pith, bark, root, leaves, sepals, petals, fruit, and even in the pollen. Raphides have been formed artificially by placing cells of rice-paper which recently have been filled with lime-water in a weak solution of oxalic acid. The artificial raphides thus formed exactly resembled the natural raphides of rhubarb.

## VIII.

In most plants the epidermis or cuticle is smooth, and apart from the features already described has few other points to interest us. In some plants, however, the cuticle forms projections called *papillæ* or warts

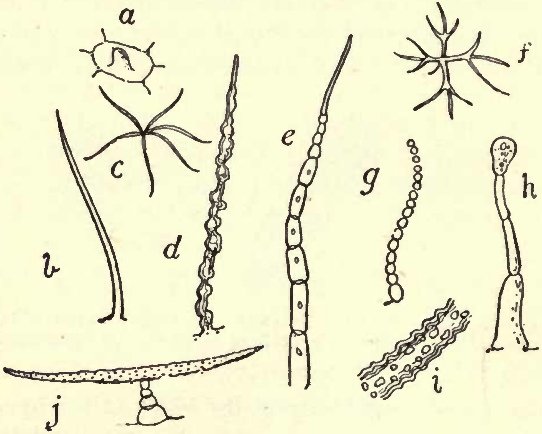
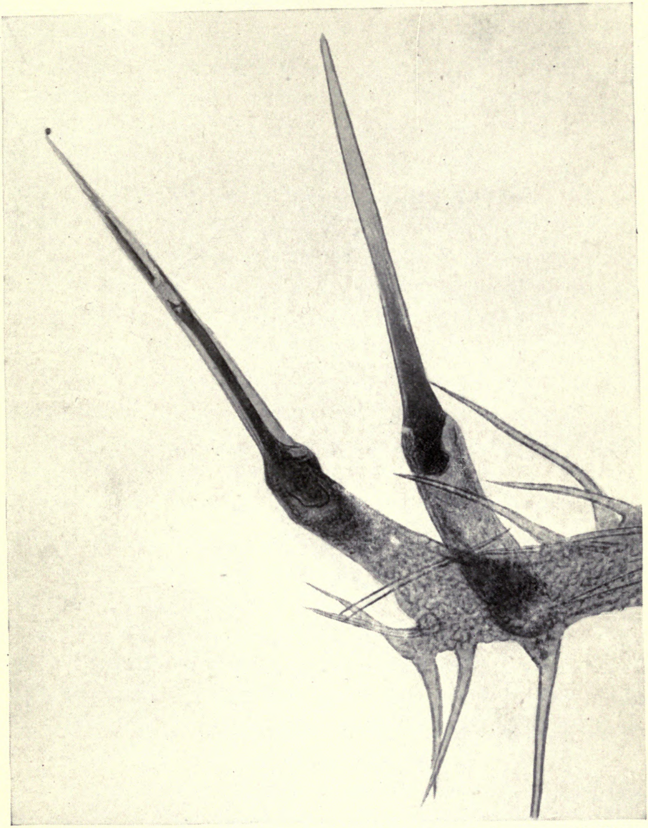



FIG. 30.—Plant-hairs. (*a*) Rudimentary hair from pansy. (*b*) Simple hair from common grass. (*c*) Star-shaped hair from hollyhock. (*d*) Hair from throat of pansy. (*e*) Many jointed, tapering hair from common groundsel. (*f*) Star-shaped hair from lavender leaf. (*g*) Beaded hair from pimpernel. (*h*) Glandular hair from tobacco leaf. (*i*) Warty-surfaced hair from verbena. (*j*) Hair from leaf of chrysanthemum.

(*i*, Fig. 30). Sometimes also there are glands, prickles, or hairs to be examined. *Papillæ* are minute swellings, and consist of one or two cells only. Warts are larger and of a harder nature. The glands contain secretions;

PLATE XX



From a photo-micrograph by] [A. Flatters

THE "STING" OF A NETTLE

the prickles are stiff and sharp, and the hairs are long and of numerous varieties. In the pansy is found an example of *papillæ* which may be considered to be a rudimentary hair (*a*, Fig. 30). There are also in the same flower others which are longer and more closely resemble true hairs. Others again are yet longer, and present the appearance of a knotted branch, due to the sides of the hair having drawn together (*d*, Fig. 30). Simple hairs may be found on many grasses, such as wheat, barley, and oats (*b*, Fig. 30). The hairs of groundsel are composed of several cells, each of which has a separate nucleus (*e*, Fig. 30). The pimpernel has hairs resembling a string of beads (*g*, Fig. 30), while those of the chrysanthemum leaf are branched and resemble the letter T (*j*, Fig. 30). Star-like hairs are found on the under-surface of the leaf of the hollyhock (*c*, Fig. 30), and branched star-like hairs are found covering lavender (*f*, Fig. 30).

Plants belonging to the same species have similar kinds of hairs, so it is quite possible to identify a species of plant by examining only the hairs of its leaves. For instance, the hairs of the tobacco plant are very characteristic, for they terminate in a knob (*h*, Fig. 30), and the quality of tobacco may be tested by the presence of these hairs. Though tobacco leaf may be imitated and the mixture adulterated, it is impossible to imitate the peculiarities of these microscopic hairs.

Some plants have hairs with glandular cells, which secrete oily or resinous matter. The leaves of the stinging nettle are a well-known example, for the hairs have glands containing an irritant fluid at their roots. The ends of these hairs terminate in an extremely fine point, so delicate that it is broken off by the slightest touch, and the poisonous fluid flows out, entering our flesh and causing the " sting " (Plate XX.).

## CHAPTER VIII.

## FLOWERS.

### I.

FLOWERS, beautiful though they always are even without any optical aid, appear much more so in the microscope. The wonders of their construction, the marvellous delicacy of their minute parts, and their gloriously beautiful colouring are a thousand times more wonderful when magnified. Petals, sepals, stamens, and pistils all have a story to tell, and only await the coming of the botanist to lay this bare.

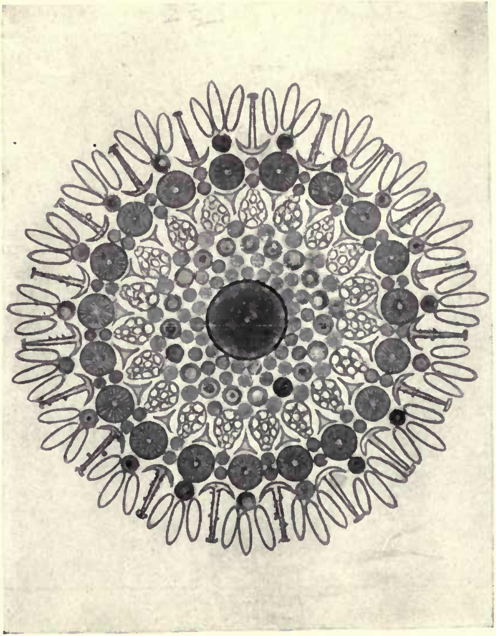
Grasses furnish us with many examples of minute flowers, which are revealed in all their beauty under the microscope. The tiny floret of the meadow-grass, for instance, exhibits stamens covered with pollen, and feathery stigmas attached to a minute ovary. The lily-of-the-valley—a larger flower than that of meadow-grass—is of triplet structure, and is of great beauty. The leaf, even to the unaided eye, shows parallel veins, and the single seed chamber, if examined carefully and in detail, will furnish much interesting information.

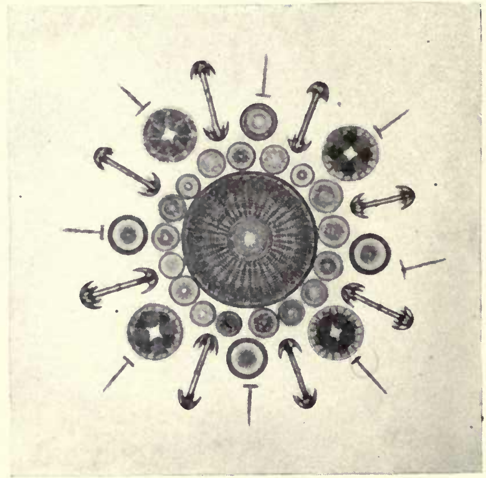
Among the most interesting of flowers are the orchids, of which many thousands of species are known. They are more common in the tropics than in our northern latitudes, and many have been the exciting adventures of orchid hunters. You may have read accounts of their exploits in more than one book. Some of the exotic or foreign orchids have been successfully cultivated in England by imitating the natural conditions of heat and moisture of the forests of the Amazon, of India, and of other countries. We ourselves may not be so fortunate as to be able to examine any of these exotic species, but we may look for some of the more lowly members of the great family which grow wild in this country. For instance, in June and July the spotted orchis is found in chalk and limestone districts. The bee orchis and the fly orchis suggest the peculiar shape these flowers take.

In the case of most flowers, the beautifully marked tissue of which they are composed is worthy of examination. Spiral fibres, such as have already been described, may be found also in these cells. The fibres are well seen in the anthers of the furze, while in the dead white nettle they are found growing in an irregular manner. In the anthers of the narcissus the cells are almost completely annular, and look like a number of disconnected rings. Yet another form is that of the star-shaped fibres of the crown imperial which radiate from a central point.

The cone-bearers, the pines and firs, also present many objects of interest—the peculiar fibre-like appearance of the cones, the cellular construction of the "pine-needles," and the resinous juices often found oozing from their branches. The catkin-bearing trees—such as the willow, birch, and alder—have curious flowers and seed

PLATE XXI





From photo-micrographs by] (a) (b) [E. Cuzner, F.R.M.S.

GROUPS OF DIATOMS AND SPONGE SPICULES

vessels, which abound with microscopic objects. So too do the members of the highest order of dicotyledons, the *Ranunculaceæ*, or rose family. These include the fruit trees—such as plum, apple, cherry—and all flowers which resemble a rose in their structure.

Such flowers as the daisy and the dandelion are not single flowers like the buttercup and the rose. When magnified they are at once seen to be colonies of flowers, that which we call the daisy being really made up of a number of very small flowers. These flowers belong to

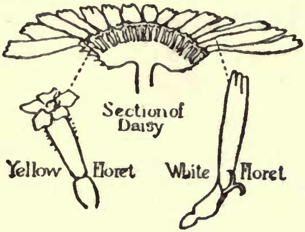



FIG. 31.—Section of a daisy.

the *Compositeæ*, the composite or compound flowers. Cut through the flower-head of a daisy and you will see the yellow florets are quite separate and resemble small bell-shaped tubes (Fig. 31). When matured or fully grown they show two tiny stigmas outspread. Inside the tube of the floret is a ring of stamens, with their pollen cases or anthers lying side by side, forming a tube enclosing the pistil and lying within the floral tube itself. This anther tube is a distinctive feature of the flowers of the family to which the daisy belongs.

The white florets outside the yellow are not so numerous as the latter, but are more conspicuous by their shape and size. They attract insects, just as do the markings and similar features on other flowers, directing them to where the nectar is secreted. The white floret has a short tube with a long blade-like ending (Fig. 31). A pistil with two stigmas may be seen in the tube, but no stamens exist. The pistil is not affected by pollen, and therefore does not produce any seeds, the work of reproduction being accomplished by the yellow florets.

## II.

Whenever possible collect and examine pollen grains from different flowers, for they vary in shape and size,

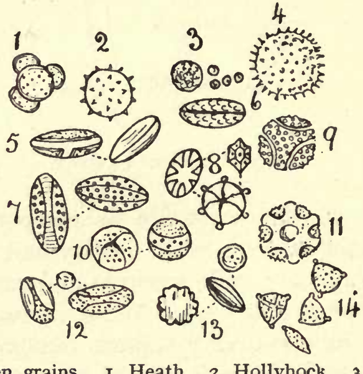



FIG. 32.—Pollen grains. 1. Heath. 2. Hollyhock. 3. Buttercup. 4. Mallow. 5. Tulip. 6. Rose. 7. Iris. 8. Clematis. 9. Passion-flower. 10. Anemone. 11. Dandelion. 12. Auricula. 13. Primrose. 14. Hazel.

each species of plant having its own particular form. It would be interesting for every possessor of a microscope to study all these different appearances, recording in an observation book the varying features of each, and perhaps giving a rough sketch of the pollen grains described.

The pollen grains of many plants are oval (5, 6, etc., Fig. 32). Those of the hazel are triangular (14, Fig. 32); those of the heath, three-lobed (1, Fig. 32). Those of the dandelion, and of many other plants of the *Compositeæ* order, are beautifully sculptured (11, Fig. 32), while the grains of the passion-flower are engraved with three rings (9, Fig. 32). Those of the hollyhock and mallow are covered with sharp-pointed spines and look like miniature pin-cushions (2 and 4, Fig. 32). These projections enable the minute grains to more easily hold fast to surfaces on which they are cast.

All these pollen grains are actual plant cells, and their purpose is to be carried to the pistil to fertilize the young ovules which form the seeds of the plant and from which young plants grow.

## III.

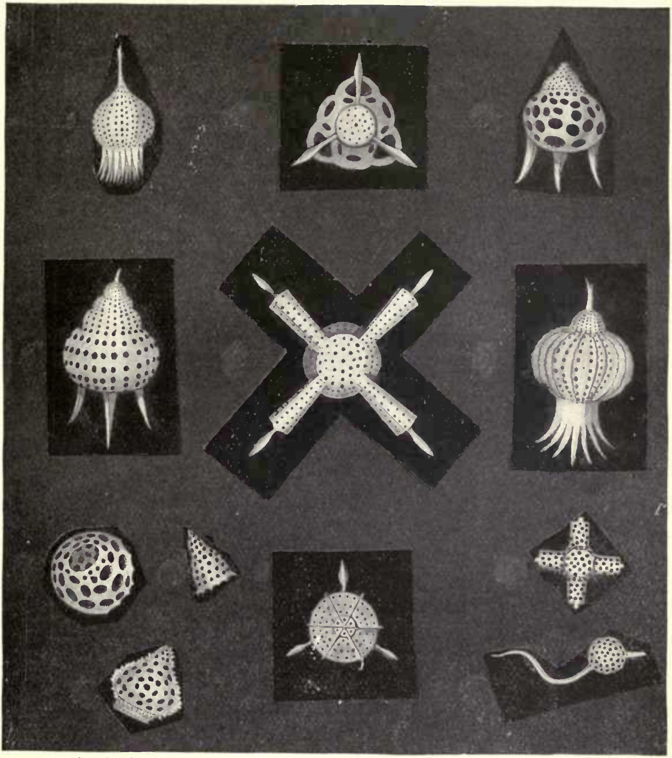
The microscope has shown us exactly how the fertilization of flowers takes place. In this great work insects, and particularly bees, are prominently concerned. Some flowers, like those of the grasses and the common hazel, are fertilized by the wind, but the majority of flowers depend upon insects for the accomplishment of this all-important operation.

Let us try to understand exactly what takes place in fertilization and why it is necessary. To enable us to study this matter we will choose a daffodil about which to speak, for this flower is both a good example and easily obtainable. We know that the daffodil is made up of "flower-leaves" and that there is no calyx as in the case of the primrose. The corolla is a deep yellow tube, and to it the flower-leaves are joined. If we cut the flower in two, down the centre, we find there is a long rod which is called the style (*b*, Plate XXIII.). At the end of this there is a sticky knob, the stigma. Six smaller rods are grouped round the style, and these are called the stamens. They are thickened at the end near the stigma, these thickenings forming the anthers. The anthers are the pollen-bearing parts of the flower, and though the position of each often varies you will find both anthers and stigma in nearly every kind of flower.

Below the corolla of the daffodil is the ovary, the chamber where the seeds are formed. In the ovary we can see, with the naked eye, a number of round objects of a transparent nature. These are the ovules, and in the course of time they may become seeds. There is, however, a remarkable difference between the ovule and the seed. If we planted one of the former it would never grow into a plant, but would simply wither away and decay in the ground. On the other hand, if we set a seed, sooner or later it would spring up and become a plant resembling that from which the seed was taken.

An ovule only becomes a seed after being fertilized, and this is accomplished by some pollen being placed on the stigma. The style is a kind of tube connected with the ovary. When the grains of pollen reach the stigma they adhere to it, because it is viscid, or sticky. The viscid. sugary secretion with which it is covered stimulat-

PLATE XXII



From a drawing by] [Ellison Hawks

*POLYCYSTINA*

ing the pollen grains to growth, causes them to sprout and send out long shoots called pollen tubes. These pollen tubes grow down the style, forcing their way between its cells (Fig. 33). They often attain an extraordinary length, sometimes extending for several inches.

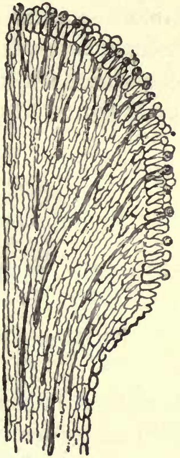


FIG. 33.—Pollen tubes seen growing on section of stigma.

The cells of the style also contain a sugary liquid, and these further nourish the growth of the pollen tubes, which ultimately reach the ovary where the ovules are found. Each ovule has a minute opening called the *micropyle*, or "little gate," and here the pollen tube enters. Having done this it pours into the ovule nutrition from the pollen grain above, the ovule undergoes certain important changes—called fertilization—and then becomes a true seed.

## IV.

Just as the pollen grains form an interesting study, so too do the seeds of plants, and, as in the case of the former, they vary in form and size in different plants. As we have seen, after the ovule has been fertilized it becomes a seed, containing the embryo or young plant. In many plants the seed is sufficiently large to be seen by the unaided eye, but the microscope will undoubtedly reveal new features of interest. The seed is covered with an outer membrane, called the "testa," and in some cases this is often curiously marked. The seed of a red poppy, for instance, is kidney-shaped, and has peculiar reticular markings (*a*, Fig. 34). The seed of black mustard is of a more circular shape, and its surface is covered with a delicate network of fine lines (*b*, Fig. 34). The seed of the snap-dragon is covered with irregular ridges, and granular markings (*c*, Fig. 34). A somewhat similar-looking seed

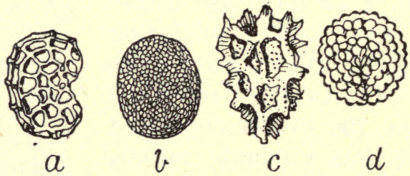



FIG. 34.—Plant-seeds. (*a*) Red poppy. (*b*) Black mustard. (*c*) Snapdragon. (*d*) Chickweed.

to that of the mustard is the chickweed, which is covered with numerous blunt projections and resembles a minute clove-ball (*d*, Fig. 34).

In some plants the seeds adhere to the fruit, which is often incorrectly called the seed. Among these are the aniseed, dill, and carraway. Some of the fruits of these plants are covered with minute hooks.

## CHAPTER IX.

## FUNGI AND MOULDS.

### I.

OFTEN when walking in the country we see mushrooms and toadstools; sometimes, too, beautifully coloured fungi are noticed on or near trees. Although all these are well known to belong to the fungus family, there are many other members of the same family which are not so well known. It is not necessary to walk into the country to find objects of this class, for mouldy cheese will provide interesting examples, as also will decayed portions of fruits and any other articles which have "gone mouldy."

We have already seen something of one-celled plants. By far the greater number of these are found living in rivers, streams, or ponds. Some, however, exist on moist rocks or on old walls. One of these is "Gory Dew" (*Palmella cruenta*), which is of very simple structure indeed, consisting simply of minute globular cells (*f*, Fig. 35). It causes a red stain to appear on the surface of damp objects, and belongs to the same family as the red snow plant.

Darwin tells us in *The Voyage of the Beagle* that during his passage of the Cordillera the footsteps of the mules in the snow were stained pale red, and a little of the snow rubbed on paper gave it a pale red tinge. The red

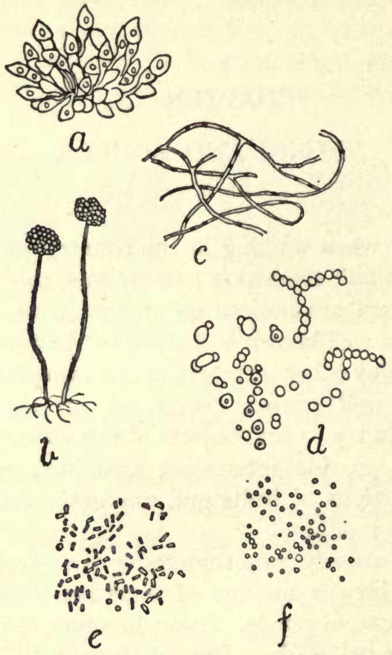
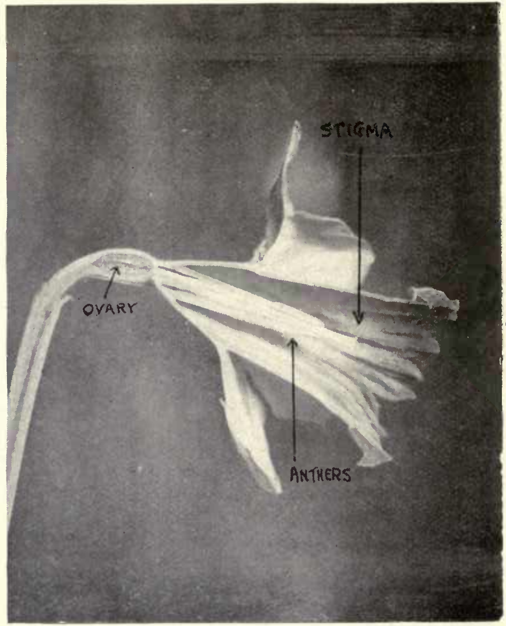



FIG. 35.—Fungi. (*a*) *Puccinia graminis*. (*b*) *Mucor mucedo*, a fungus from mouldy bread. (*c*) "Cholera-fungus." (*d*) Yeast cells. (*e*) Vinegar plant. (*f*) "Gory Dew" (*Palmella cruenta*).

colour was entirely due to the presence in large numbers of the tiny plant *Protococcus nivalis*. The phenomenon, of somewhat rare occurrence in this country, was noticed in many places after a severe snowstorm in 1908. The

From a photo-micrograph by] [A. E. Smith

(a)




From a photograph by] [Ellison Hawks

(b)

(a) *POLYCYSTINA.* (b) SECTION OF A DAFFODIL

wonderful little plant *Protococcus nivalis* appears on the surface of the snow, and so quickly do the cells reproduce themselves that an Arctic or Alpine landscape may be changed from white to red in a single night. This rapid growth of *Protococcus nivalis*, and its peculiar red colour, gave rise to many fearsome tales in olden days, for then the true nature of the phenomenon was not understood, it being thought that the snow was stained red with blood.

Examined in the microscope, *Protococcus nivalis* is seen to consist of numbers of spheres, in colourless cases, each no more than $\frac{1}{1000}$ inch in size. When perfect, the spherical cells are not unlike a red-currant berry. Minute though they are, the cells perform all the functions of growth and reproduction as completely as the larger and more highly organized members of the vegetable kingdom.

There are many other members of the same family, one form attacking bread, and another potatoes. In each case the bread and potatoes are given the appearance of having been dipped in blood.

## II.

Of similar structure is the yeast plant, or fungus, by the aid of which bread is made. It belongs to a group called *Saccharomyces*, or sugar fungi. Yeast cells furnish us with an interesting and typical example of the construction of cells, of their growth and of their method of reproducing themselves. The cells commence their life as a creamy foam, floating on the top of a brewer's vat. Under the microscope they look like a crowd of yellowish grains. Most of them float about quite alone, or isolated, but here and there are some which are joined together in chains, like beads on a string. They resemble oval globes in shape, and on an average are $\frac{1}{3000}$ inch in size (*d*, Fig. 35). Each is filled with almost colourless matter, in which are to be seen one or more bubble-like objects, or *vacuoles*.

When yeast cells are placed in a suitable liquid—or fermentable fluid, as it is called—they grow, or vegetate. Each cell then commences to put out one or two projections or buds, and looks like a large potato with a smaller one attached. These projections are the beginning of the young cells, which are really offshoots. When they are sufficiently developed they become detached and break away from the parent, forming complete cells. Later, they themselves become parent cells in their turn, and in this manner a single yeast cell develops into chains of four, five, or six cells in the space of only a few hours.

If the fermentation of the liquid in which they are placed is stopped, the cells composing these chains break away and become detached. So long as the cells remain in liquid from which they can extract food, or nutriment, the birth of new cells will continue. If the liquid in which the cells are placed becomes unsuitable—if, for instance, the sugar it contains be used up—or if it becomes dried up, the contents of the cells contract. The spores, or seed germs, then become inactive for the time being. Although they may become quite dry to all outward appearance, they are not killed, but still contain the mysterious element life. In fact, the cells are not easily deprived of their living contents by being subjected to either high or low temperatures, for as soon as conditions are once more favourable they revive and recommence reproducing themselves.

## III.

A minute vinegar plant may be cultivated by simply allowing vinegar to stand for a little time in a jar and exposed to the air. At first the vinegar plant is seen to be composed of elongated cells, looking like a collection of pieces of finely chopped cotton or thread (*e*, Fig. 35).

More fully developed thread-like fungi are often found in decomposing fluids. One of them is misnamed "Cholera-fungus," which was at one time believed to be the cause of cholera (*c*, Fig. 35). Sometimes specimens of this fungus may be obtained by exposing a piece of damp glass or similar substance to the air in a damp and unwholesome cellar or room.

It is believed that all these simple fungi are really different forms of the fungus which produces the common mould known as *Muccr mucedo.* This mould—which is found almost everywhere—attacks jam, fruit, and vegetables, especially those of a sugary or starchy nature. Sometimes we see peaches and other delicate fruits wrapped in cotton-wool or tissue paper. The wrapping acts as a preventive against mould, which quickly attacks bruised fruits, the spores obtaining an entrance to the fruit through the openings in the skin caused by the bruises.

If we carefully collect some common mould and examine it with the microscope, we find that the main mass—

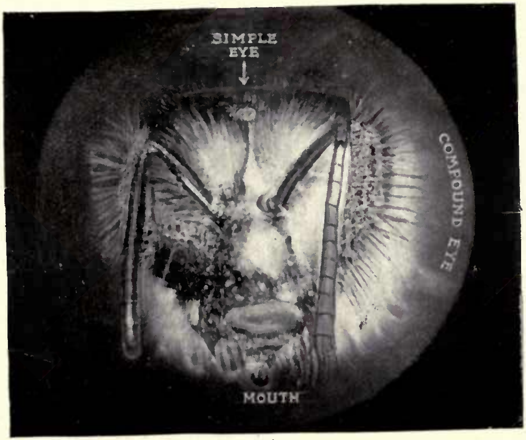
known as the "mycellium"—is composed of a large number of *hyphæ*, or knob-like structures; they stand upright, and each one terminates in a round swelling (*b*, Fig. 35). These round objects are the *sporangium*, or seed cases, as they may be called, and contain thousands of minute oval bodies, named the endo-spores. When these are ripe they burst, and the spores are scattered in all directions as a very fine, invisible dust.

Mould is found almost everywhere where there are substances which are exposed to damp and decay. We find moulds in our gardens, in our houses, in our food, and in our clothes. A form of mould even is often able to obtain a sufficient supply of nourishment to exist in the paste of wall-paper and in old books. Sometimes moulds look like spots or markings on the leaves of plants. At others they appear as mildew, smut, or rust. These latter names do not mean the smut of the factory chimney, nor the rust of old iron; they are the names given to moulds because they closely resemble these objects in appearance. The smut mould on plants is a dirty-looking growth, and the rusts are growths of a distinctly reddish colour.

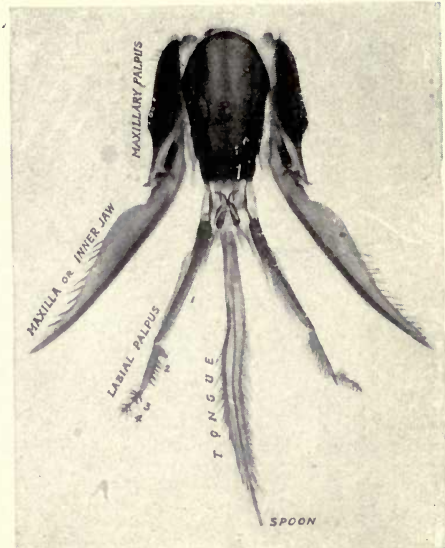
## IV.

One of the most troublesome of these moulds is that called "corn mildew," although it sometimes attacks wheat and other grasses as well as corn. It is caused by a fungus called the *Puccinia graminis*. This particular form of mould has been closely studied with the microscope, and it is now believed that it commences its existence in the berberry plant, the leaves of which when attacked

PLATE XXIV




(a)




(b)

From photo-micrographs by] [Ellison Hawks

(a) HEAD OF BEE. (b) TONGUE AND MOUTH PARTS OF BEE

appear to be covered with a fine red rust. Under the microscope these rust-like markings are seen to consist of myriads of structures resembling minute cups in shape, and filled with orange-coloured dust (Fig. 36). This dust is the spores—or microscopic seeds—of the fungi, and it is estimated that each minute cup contains no less than a quarter of a million spores! Later, the fungus passes through different stages, at one time having the appearance shown at *a*, Fig. 35.

FIG. 36. — Cluster-cups on underside of leaf.

The corn mildew is so common, and its spores so numerous, that they mingle with the seeds of the grain when ground into flour. If carefully looked for they may be found in almost any piece of bread, if it be examined under the microscope.

## V.

Fungi often attack plants and cause irregular spots to appear on their leaves. These are generally seen in summer and autumn, and may be of a yellow, red, or black colour. A common form, and one much dreaded in many parts of the country, is the potato disease—as it is commonly termed. There are several forms of this disease, but that generally met with is *Phytophthora infestans*, also called " the late blight." This fungus is found wherever the potato is grown, and in this country generally appears about July or August. The leaves of the potato lose their brilliant green colouring, becoming mottled and patched with yellow. They gradually change to dark brown and perhaps even to black. Sometimes the stems themselves are affected.

The tubers, as the potatoes are called, accumulate starch and other matter. For the formation of this starch they depend entirely upon the leaves, which form it with the aid of sunshine. Thus, it is quite easy to understand that if the leaves are attacked by the mould, and die, the tubers do not grow to their full size. Instead of the potatoes being large and healthy they are much smaller, and the crop is diminished. In countries like Ireland, where the poorer people depend for their food mainly upon potatoes, it may be a very serious thing if the disease attacks the crops.

## VI.

Many forms of fermentation are due to the action of microscopic fungi. There is, for instance, that form which takes place in wine-making. The fermentation of the juices of the grape—or whatever other fruit is used—commences with the development of a minute fungus, the germs of which were already present in the fruit, or in its skin, when it was gathered.

The common drink in Japan is a kind of beer called *saki*, and this is made by fermenting rice. Another drink made by the Japanese is *soy*, which is obtained by mixing the beans of the *soja* with an equal quantity of roughly ground wheat or barley, which is then placed in a warm place to ferment. In both these cases the action is due to a microscopic fungus which, by feeding on certain substances in the mixture, causes a chemical change to take place. This change is called fermentation.

## VII.

There are also numerous lichens, mosses, and ferns which abound with interest to the microscopist. One particular form of lichen, of a yellow colour, is often seen on railings and on the bark of trees. It resembles pieces of dried yellow paper, and is composed of scales which show on their surface spots of deeper yellow colour. Cutting through these, we find a number of cases, or *asci*, containing the spores.

In marshy ground the bog-moss *Sphagnum* is often found. This moss, during the War, was collected in many parts of the country, for it forms a valuable surgical dressing, better even than cotton-wool, and has been largely used in the healing of wounds. The leaves are a splendid example of fibro-tissue, and well illustrate the development which takes place in tissue, if examined day by day.

## CHAPTER X.

## MARINE LIFE.

### I.

IT is not all of us who are so fortunate as to live by the sea ; but in normal times it is reasonable to suppose that most of us may visit the seaside at some time or other during our holidays. During such a visit we may take the opportunity of collecting a quantity of material for examination under the microscope, either during some wet day of our holiday or to take home with us for dealing with at leisure.

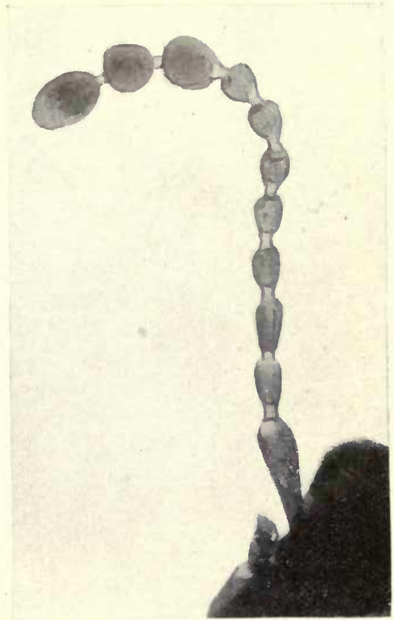
Living in sea water we find plants and animals closely resembling those of fresh water. Indeed they belong to the same families, although of entirely different species. There are, for instance, many forms of minute seaweeds which belong to the same families as the diatoms and the *Coniferæ*. The structure of the fruit-bearing organs of the larger seaweeds are very interesting under the microscope. A frond of " bladder-wrack " shows swollen masses in certain places, covered with rough bodies of yellow colour. These contain spores, which carry delicate hairs of various forms.

PLATE XXV

From photo-micrographs by]

(a)


(b)



[Ellison Hawks

(c)

*ANTENNAE*

(a) Wasp. (b) Bee. (c) Beetle

## II.

There are also numbers of minute marine animals which are of the greatest interest to us. Among the most lovely forms are the sponges, which are composed of animal matter combined with horn, chalky, or flinty substance. This forms a network which may be seen by cutting with a pair of sharp scissors a thin section from a bathroom sponge (*a*, Fig. 37). Other forms of sponges

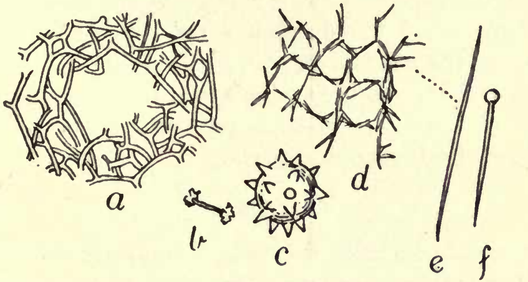



FIG. 37.—Sponge spicules. (*a*) Section of common sponge. (*b*) Spiculum from fresh-water sponge. (*c*) Spiculum from *Tethea*. (*d*) Section of common British sponge. (*e*) Spiculum of (*d*) magnified. (*f*) Pin-shaped spiculum from *Cliona*.

may be found with seaweed on the seashore, and these show a network composed of sharp, needle-like objects, or flinty spicules, as they are called (*d*, Fig. 37). These spicules lie one over the other and differ in form and size in various sponges. In fact, so pronounced and well known are their differences that it soon becomes quite easy to identify the species of a sponge from the shape of its spicules. Some spicules are pin-headed, as in the case of *Cliona*, a little boring sponge, found in the shells of old oysters (*f*, Fig. 37). Another well-known spicule is one shaped like a delicate dumb-bell and belonging to the fresh-water sponge (*b*, Fig. 37). Some spicules—as in the case of *Tethea*—are round and covered with pointed projections, reminding us of part of a mace, one of the curious weapons of war in use in the olden days (*c*, Fig. 37). Sometimes sponge spicules are mounted along with diatoms to make beautiful designs; Plate XXI. shows two of these slides. In *a* spicules resembling minute pick-axes alternate with groups of three navicular diatoms. In *b* the dumb-bell type of spicule is to be seen, and there is also another kind, looking like a delicate corkscrew, the whole forming a pleasing figure and a very eloquent testimony of what patience can do in the arranging of microscopic objects.

## III.

We must now leave the sponges and learn something of another and equally interesting class of object found in the sea. These are the *Foraminifera*, a name derived from the Latin words *foramen*, "an aperture," and *fero*, "to bear." The *Foraminifera* are simple animalcules, like the *Amœba*, but possessing the power to surround themselves with a chalky or calcareous shell. These shells have tiny holes in them, and hence their name, which means "the hole-bearers." To form their shells, the little creatures collect the carbonate of lime contained in the sea water, and surround their bodies with it. Some *Foraminifera* construct their shells of minute sand grains, and these are called "tests." Both kinds of shells are almost indestructible, and, in the case of fossil *Foraminifera*, have lasted through the ages. During this time they have often undergone great pressure in the Earth's crust, still remaining unbroken and perfect.

*Foraminifera* are larger in size in the waters of the warmer oceans than they are in the waters of the polar seas. As we have already mentioned, the shells vary

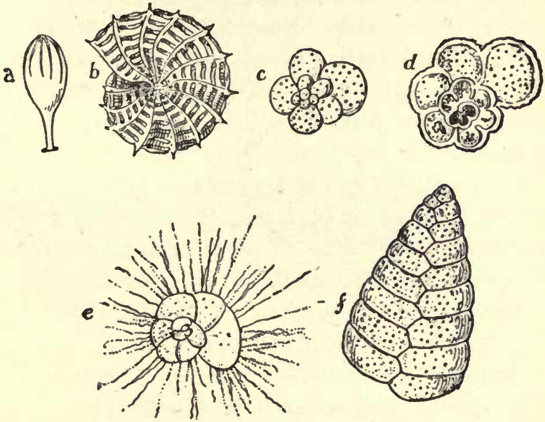



FIG. 38.—*Foraminifera.*

greatly in design. Some (like the kind called *Largena*) consist of a single chamber and resemble a small Indian club (*a*, Fig. 38). Others, like *Globigerina*, are a cluster of chambers arranged spirally (*c*, Fig. 38). The younger *Globigerina* shells number from eight to twelve chambers, and are thin and smooth; but the older shells may consist of sixteen or even more chambers, and are much thicker.

Often *Foraminifera* may be found alive among the roots of the giant seaweeds generally found on the shore after a storm. If the roots be washed, and the water therefrom be allowed to stand, the *Foraminifera* will sink to the bottom, and may then be picked out and examined.

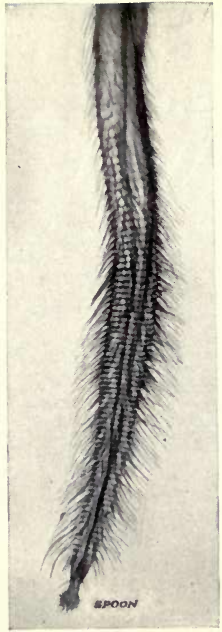
Some *Foraminifera* so closely resemble the nautilus, that early naturalists did actually include them in the same class of shell-fish. Now, however, it is well known that the animal bodies of the two creatures are quite distinct from each other. There is also an important difference. The nautilus, although it forms chambered cells, lives in the last formed chamber. It adds a larger chamber when the size of its body so increases that it is necessary to give more room, withdrawing from each chamber in succession. The *Foraminifera* which so closely resembles the nautilus in appearance is not a single-bodied animal but has a composite body, consisting of a number of segments connected one to the other by a filament or membrane. It continues to increase by "budding," and as each new segment is formed a new chamber is added to the shell. Thus—unlike the case of the nautilus—each chamber of the *Foraminifera* is occupied by a segment of the animal's body.

## IV.

Until forty or fifty years ago very little was known about the floor of the ocean. Some people knew that our oceans were so deep in certain places that the depth could be measured only in "miles," but that was about the extent of our knowledge. Some scientists argued

From photo-micrographs by]

(a)




(b)

[Ellison Hawks

(c)

(a) LEG OF BEE, SHOWING WAX-PINCERS. (b) TONGUE OF BEE. (c) FOOT OF BEE

that nothing could live in water so deep, where the sea floor was in total darkness, and expressed the opinion that the pressure of the water itself must be so great as to forbid the existence of life of any kind. However, a kind of net and basket called the deep-sea dredge was invented, and with this the floor of the ocean at its deepest places was explored. The dredge was lowered from a ship, which meanwhile travelled slowly along and dragged the dredge with it. The dredge was then hauled to the surface and, to the wonder of all, numerous delicate forms of life were found in it.

Among the multitude of interesting objects which the deep-sea dredge reveals, is a light-coloured mud or ooze. This ooze is nearly wholly composed of *Foraminifera* shells, the largest of which are less than a pin's head in size. The celebrated German naturalist Ehrenberg estimated that one cubic inch of ooze contained over 1,000,000 of these shells. They are of all manner of shapes, some having one chamber, others several. There are straight shells, curved shells, flat shells, round shells, coiled shells, and oblong shells. Some are white and chalky looking, others resemble pearls, and others, yet again, are clear and transparent like glass. All the shells from the ocean floor are empty, for they are shell-cases only. If we scoop up some of the tiny shells which float on the surface of the ocean and in its waters, however, we find they have living creatures inside.

*Foraminifera* are found in greatest numbers in mud or ooze dredged up from the bed of the Atlantic, but many varieties may be obtained from the sands around our own coasts. They also live in rock pools or attached to seaweeds. If placed under the microscope in some sea water, the curious action of the *pseudopods* may be seen. When the shells are to be mounted on slides they must first be boiled in a strong solution of potash; this destroys their animal contents, but does not injure the shell. The shells may also be obtained from chalk cliffs and separated by placing the chalk in water until softened.

*Foraminifera* are divided into two groups, called *Imperforata* and *Perforata*. In the former group are classed those shells which have one main opening (or sometimes more), and in the latter group the shells which, in addition to the main opening, have perforations through the walls.

## V.

No doubt many of you have seen the chalk deposits in one part or another of our Island. On the east coast of Yorkshire, at Bempton and Flamborough, the cliffs are several hundred feet high. The chalk cliffs near Dover are known to the sailors as "the white walls of old England." London is built on chalk, as is also Paris; and similar rocks to these are found extending over France, Denmark, and Central Europe. They reach also from Northern Africa to the Crimea, and from Syria to the Sea of Aral in Central Asia.

All these chalk deposits consist largely of the remains of *Foraminifera* shells. When their inhabitants die, the shells sink to the bottom of the ocean, and there form the fine mud or ooze to which we have already referred. The shells are always falling, as lightly as motes in a sunbeam, sometimes through thousands of feet of ocean depth. It is just as if a continuous snowstorm was taking place in the sea, the flakes of which are just as beautiful when seen in the microscope as are snowflakes when similarly viewed.

This rain of shells is going on at the present time, and exactly the same happened ages ago. Far back in the Earth's history countless millions of these shells fell day and night, century after century. *Foraminifera* inhabited the prehistoric oceans, just as their descendants live in our seas to-day. Every drop of water was alive with them, and they were so numerous that the floors of the oceans in which they lived soon became covered with their shells. As they continued to fall, so did their shells continue to accumulate, until—after the passing of many millions of years, perhaps—they formed the chalk deposits which we know to-day. These deposits of chalk are called by geologists the cretaceous rocks, from the Latin word *creta,* which means "chalk." The deposits have been lifted high above the level at which they were formed by Earth movements, and they show us that in times gone by there must have existed great seas where they occur. For instance, the cretaceous rocks tells us that at one time South-East England, France, Germany, Poland, Russia, Egypt, Arabia, and Syria were all under the sea.

The stone of the Pyramids consists of the fossil shells of a variety of *Foraminifera* called *nummulites* (Latin *nummulus,* "a small coin"), a species which, as its name implies, is coin-like in shape.

## VI.

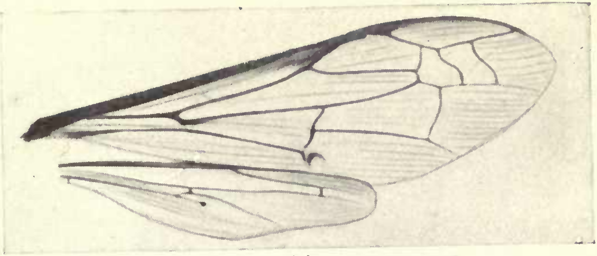
Among the most beautiful objects which the microscope can show are the *Polycystina*, a group of *Radiolaria* (Plate XXII.). The name is derived from the Greek *polus*, "many," and *kustis*, "a cyst or box." They are of all shapes, and are covered with minute perforations through which the creature inside could thrust its *pseudopodia* and capture food, or propel itself through the water. If *a*, Plate XXIII., be examined with a magnifying glass, some of the more common varieties may be seen. When seen on a dark background *Polycystina* look like miniature jewels. They are obtained from the chalky-looking Barbadoes earth, which is sometimes used for polishing purposes.

## VII.

Another interesting animal which lives in the sea is *Noctiluca miliaris*, a name which means "thousands of nightlights." To this minute animal is due the peculiar phosphorescent appearance often seen in the sea. Describing the phenomenon Darwin, in his famous book, *The Voyage of the Beagle*, says: "While sailing a little south of the Plata on one very dark night, the sea presented a very wonderful and very beautiful spectacle. There was a fresh breeze, and every part of the surface which, during the day, is seen as foam, now glowed with a pale light. The vessel drove before her bows two billows of liquid phosphorus, and in her wake she was followed by a milky train."

Another writer has described the phenomenon as

PLATE XXVII



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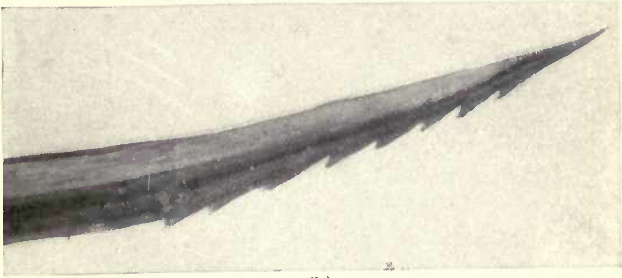

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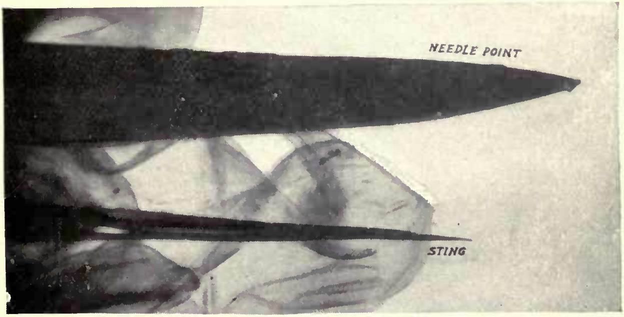



From photo-micrographs by] (c) [Ellison Hawks

(a) WING OF BEE. (b) STING OF WASP. (c) STING OF BEE AND NEEDLE COMPARED

follows: "In certain oceans and seas, in calm weather, when the nights are dark, the wake of the passing ship resembles a path of oscillating gold, increasing in brilliancy until it glistens in whiteness. The contrast with the surrounding black waters becomes most impressive. The boatman puts off from the shore, and as he dips his oars and lifts them up the dripping waters sparkle as if illuminated by thousands of microscopic arc-lamps, while the prow of his boat cuts its way through liquid brilliants. A gentle ripple is sufficient at certain times to cause the luminosity to appear, but when the sea is absolutely smooth there is no observable display."

The peculiar phosphorescent light which *Noctiluca miliaris* emits may be seen even when only a comparatively small number of the creatures are contained in a jar. If the jar be gently shaken, or knocked, the little captives instantly emit a soft light, of a beautiful greenish hue. This is strong enough to be seen even by lamplight. It only lasts for an instant, however, and the animals require a short rest before it can be renewed.

*Noctiluca miliaris* belongs to a group of the *Protozoa*, and is about $\frac{1}{60}$ inch in diameter. It can just be seen by the naked eye if the water in which it is contained is held up to the light. With a hand magnifying glass its *flagellum*, or tail-like appendage, is visible. *Flagellum* is a Latin word meaning "a little whip," and the presence of this feature distinguishes that group of *Protozoa* to which *Noctiluca miliaris* belongs, from the group of which *Amœba* is a typical example. *Flagella* are long, slender filaments, usually few in number, and are used both for obtaining food and for moving about through the water. The former is accomplished by vibrating the *flagella,* which sets up currents and whirlpools; particles of food are thus drawn to the animal's mouth. The motion of the animal through the water is accomplished by a peculiar lashing movement, which causes the animal to be dragged along in jerks or leaps.

## CHAPTER XI.

## AN INSECT LABORATORY AND WORKSHOP: THE HONEY-BEE.

### I.

IN this little book we have not sufficient space to learn everything about the many kinds of insects and their varying appearances in the microscope. Instead, I intend to tell you a little about only one insect, so that you may learn from it something of what applies to all insects generally. The insect which I have chosen for the purpose is *Apis mellifica,* the honey-bee, because not only is it well known to all, and sufficiently common for specimens to be easily obtained, but it is one of the most interesting of all the members of the insect world.

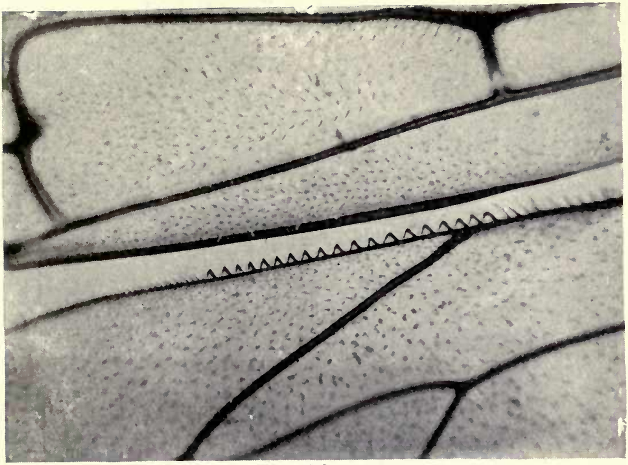
We cannot here consider the wonderful story of hive-life—that has already been told in another volume of the series to which this book belongs.* In these pages we are more concerned with the aspect of the bee as shown by the microscope, and with an examination of the wonderful limbs and the parts of its body which enable it to turn nectar into honey, and to manufacture the wax required for the comb. We must see something also

* *Bees: Shown to the Children.* By Ellison Hawks.

of the tools with which it collects the pollen, builds the cells, and accomplishes the numerous other processes required of it in its daily life.

## II.

The bee is a typical insect, having head, thorax, and abdomen. The head is something like half a split pea in shape, with the rounded part turned to the front, and is joined to the thorax by a thin neck. There are five eyes, two compound and three simple, and it will be as well if we note here the difference between the two types of eyes. Spiders possess only simple eyes, but the bee has both compound and simple, as I have mentioned. In the case of the bee, the compound eyes are placed one on each side of the head, and are large and prominent, like those of the house-fly. The simple eyes are to be found at the top of the head, and are hidden away in the fine golden hairs with which the head is covered (*a*, Plate XXIV.). The compound eyes are of a deep, purplish colour, and glisten like satin. They are made up of a multitude of hexagonal, or six-sided, cells similar in shape to those of the honeycomb. These cells are called facets, which means little "windows," and each one measures about $\frac{1}{1000}$ part of an inch in diameter. Each facet is really a small eye in itself, and that is the reason the eyes are called compound. In the eye of the worker bee there are over 6,000 facets, each one pointing in a slightly different direction. Large though this number appears to be, it is less than half the number possessed by the drone, whose facets number 13,000 in each eye. The queen-bee has about 5,000.



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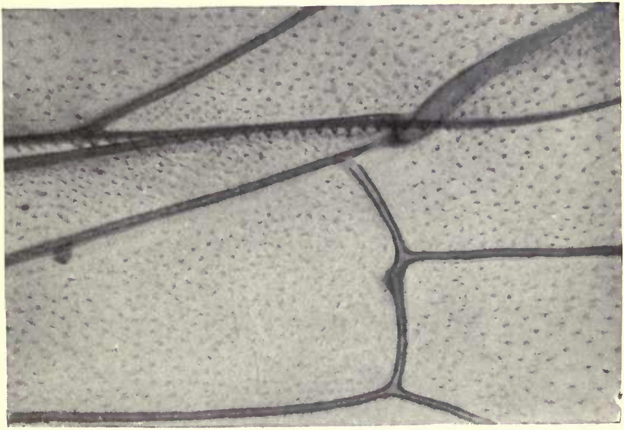


From photo-micrographs by] (b) [Ellison Hawks

HOOKS ON WING OF BEE

(a) Unlocked. (b) Locked

Each facet acts as a minute lens. With a camera a photograph may be taken of any object at which it is pointed, for the lens with which it is fitted throws an image of the object on the photographic plate. Our own eyes act as lenses, and throw an image of whatever we look at, not upon a photographic plate, but upon a sensitive surface called the *retina*, a Latin word meaning "a small net." The retina catches the picture from the crystalline lens of our eye and passes it on to the brain, where we "translate" it, as it were, and understand it. Each facet in the compound eye acts as a minute lens. At one time it was believed that each facet made a separate image of the object at which it was directed, but this is not now generally believed to be the fact. It is realized that it is unlikely that Nature would provide an eye to show several thousands of flowers instead of the one at which the eye was directed. It seems much more probable that each facet forms an image of only that part of the object which is exactly in front of it, all the pictures combining to form a single image, just as the small coloured bricks in a mosaic work combine to form a pattern.

The simple eyes are arranged so as to form a triangle, like this ∴ In the case of the drone the compound eyes are so large that they extend not only over all the space at the side of his head but also right over the top, covering the position occupied by the simple eyes in the worker. On account of this the drone's simple eyes are placed lower down on the front of his head, the position approximating more to that of our own eyes.

The simple eyes are so called because they do not seem to be nearly so complicated in their construction as the compound eyes, but nevertheless they have an elaborate structure.

Over the surface of the compound eye are distributed numerous long, straight hairs. Their chief purpose is to protect the facets, just as the eyelashes of our own eyes protect them. The simple eyes have tufts of hair, like eyebrows, surrounding them, but these are so placed that they do not interfere with the range of vision. Bees have no eyelids as we have, so they have to rely upon these hairs to protect their eyes from dust and other foreign bodies.

## III.

In addition to the eyes, the head carries the *antennæ*, or "feelers," as they are commonly called. The *antennæ* of the worker bee each consists of a single long joint and eleven small joints (*b*, Plate XXV.). The long joint is called the "scape," meaning a shaft or stem, and the smaller ones are said to form the *flagellum*, which, as we have already seen, means "a little whip." The *antennæ* of the drone, whilst resembling those of the worker, have one more small joint in the *flagellum*, thus making the total number twelve. They are fixed to the bee's head by a cup-and-ball joint, and can be moved in practically any direction. In addition, each of the joints of the *flagellum* can be moved separately.

The scape is covered with numerous hairs, which are both long and fine. The first three joints of the *flagellum* are also covered with hairs which, however, differ in appearance from those of the scape, being much shorter and thicker. They look more like bristles, and all point in a downward direction. The remaining eight joints are covered with multitudes of still smaller hairs, and these again differ in their construction. The hairs on the *antennæ* of a drone number about 4,000, and on those of a worker about 28,000. Each hair is connected with a nerve so sensitive that the most delicate touch can be perceived immediately.

The *antennæ* serve many useful purposes, and are of a wonderful and complicated structure. In the hive, although it is dark, the bees are able to find their way about by means of them. They build their combs with their aid, and with them they communicate with each other. Watch bees on the alighting board of a hive, how they approach and gently cross their *antennæ*, as two duellists cross their swords before a fight. For a fraction of a second one seems to lightly tap the *antennæ* of the other, and it is obvious that a communication is passing between them.

In the *antennæ* are the nerves with which bees smell. The "smell hollows," as they are called, are exceedingly numerous and minute. Each of the last eight joints of some worker bee's *antennæ* have fifteen rows of twenty "smell hollows," a total of over 2,400 in each *antenna*. The queen has only about 1,600, but the drone has 37,000 on each *antenna*.

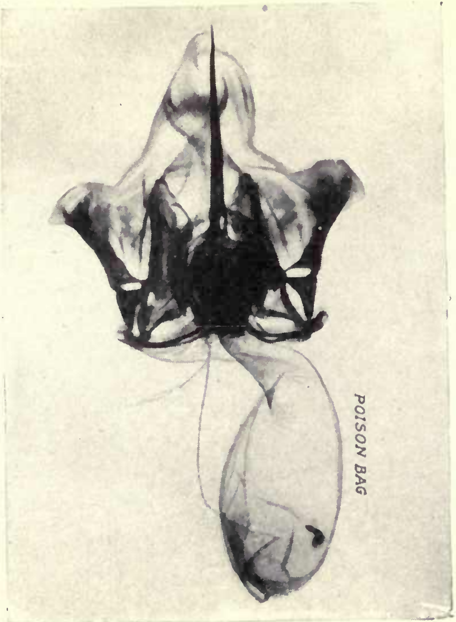
Here also are found the ears of the bee. We generally expect to find the ears of living creatures in their heads, but Nature sometimes plays queer tricks in the animal world. For instance, who would dream of looking for the ears of a cricket in its legs? Those of the grasshopper are found in a similar place. Then there is a kind of shrimp, called the *Mysis*, which actually has its hearing apparatus in its tail! Thus, when we remember these peculiarities it is perhaps not quite so strange as it at first seemed to find the bee's ears in its *antennæ*. The ears take the form of oval-shaped holes or depressions, and are quite distinct from the "smell hollows" already mentioned. They measure only about $\frac{1}{10000}$ part of an inch in size, and each is surrounded by a minute ring of bright orange colour.

The central part of the *antennæ* is hollow and contains the nerves which run like a bundle of electric cables to the *ganglia*. *Ganglia* comes from the Greek and means "a knot," and it is really a knot or a bunch of nerves, for they are the "nerve centres" situated in the body. The chief *ganglion* is in the head, and corresponds to the brain in animals. Other *ganglia* are found in the thorax and in the abdomen.

## IV.

The tongue of an insect is called the *proboscis*, a Greek word meaning a "front feeder or trunk," and indeed the bee's tongue is not unlike the trunk of an elephant in appearance. The tongue itself is long and tapering, and is composed of a number of ring-like structures, covered with hairs, arranged in a regular manner, and pointing in a downward direction (*b*, Plate XXIV.). In the tongue of the queen and drone the rows of hairs number from sixty to sixty-five, but in the case of a worker, which has a much longer tongue, they number ninety to a hundred rows. Some of these hairs are used for feeling, but most of them

PLATE XXIX

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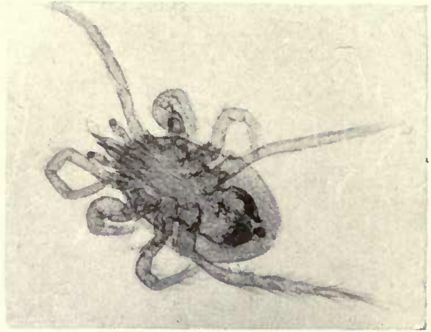

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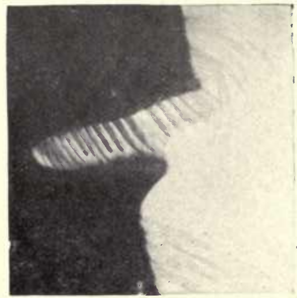


[Ellison Hawks

(c)

(a) STING AND POISON BAG OF BEE. (b) BEE PARASITE. (c) WAX-PINCERS OF BEE

are necessary for collecting the nectar from the flowers. This adheres to the hairs when the bee pushes its head into the corolla and sweeps from side to side with its tongue. The tongue is extremely flexible and can be moved in any direction. At the extreme end is the spoon, also used in collecting nectar, and covered with delicate branched hairs (*b*, Plate XXIV.). The front is composed of *maxillæ*, or inner jaws. The tongue, but not the protecting tube, can be drawn up into the bee's mouth at will. The *labial palpi* each consist of four joints, of which the two nearest the mouth are the largest. They also have numerous hairs, used for feeling as well as protection.

The *maxillæ*, or inner jaws, have already been mentioned. The outer jaws are very hard and have sharpened edges. The action of most insects' jaws resembles a pair of scissors in opening and closing. Those of the bee are very powerful and are chiefly used in the making of honeycomb, the wax of which is thinned out by their aid.

## V.

The thorax, or chest, of an insect may be likened to the engine-room of a ship, for it is the centre of all movement so far as the wings and legs are concerned. It is divided into three parts: the *pro-thorax* or forward division nearest the head, the *meso-thorax* or middle division, and the *meta-thorax* or after division. It contains several large muscles, for the bee is a powerful flier, and is thickly covered with fine, downy hairs. Among these hairs are a number of other spike-like hairs, in which pollen is entangled when the bee enters a flower.

The thorax also contains the *tracheæ*, or air sacs. These fill with air and make the body more buoyant, and thus assist the flight of the insect.

## VI.

The legs of the bee are very interesting, and nearly every microscopist is sure to have slides of them, for they are well known as "show objects." There are, of course, three pairs of legs, one pair being attached to each division of the thorax. Each leg has nine joints and terminates in two claws and a kind of soft pad (*c*, Plate XXVI.). The claws are used in walking over rough surfaces, and when wax-making the bees hang in chains or festoons from the

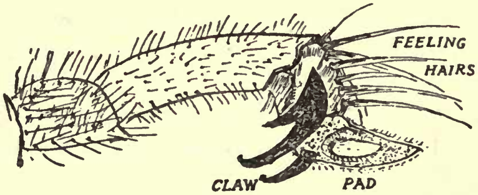



FIG. 39.—The claw and pad.

roof of the hive by hooking their feet together. The soft pad is called the *pulvillus* and is used for walking on a smooth surface or in positions in which the claws cannot be used. When the claws fail to grip any surface they slide down under the foot, and the pad is thus automatically brought into action, for it presses against the smooth surface and adheres to it by means of the viscid moisture with which it is covered (Fig. 39).

The legs nearest the head are the shortest pair, and their most interesting features are the brushes and comb (Fig. 40). The brushes consist of hairs which serve two purposes, one for cleaning the comb and the other for freeing the hairs of the eye of pollen and dust. The comb is a semi-circular notch around which are arranged

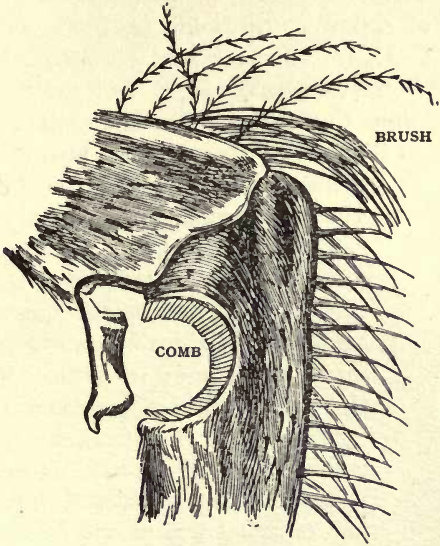



FIG. 40.—The brush and comb.

about eighty teeth. Just above is the *vellum*, a kind of hinge or lid, and so named because it "covers" the *antennæ* when it is drawn into the comb and holds it there whilst it is being pulled through. This operation is performed by the bee bringing its front leg to its head and then moving the leg outwards. By this movement the *antennæ* is drawn into and through the comb, the teeth removing any dirt and pollen which may be adhering to it.

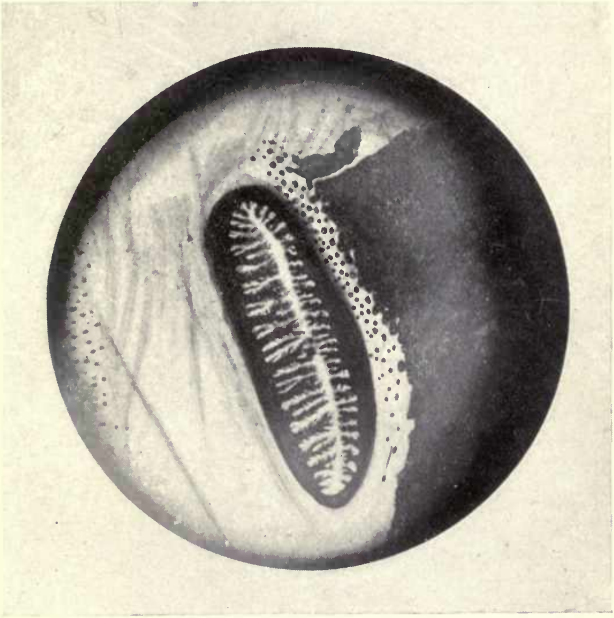
The second pair of legs have a kind of stiff spike used for cleaning the wings. The hindermost pair are the longest, and are furnished with wax-pincers consisting of a row of spikes at the joint (*a*, Plate XXVI., and *c*, Plate XXIX.). The *corbicula*, or pollen basket, is also found in the hindermost legs. In it pollen is carried from the flowers to the hive. The large joints, or thighs as it were, of this pair of legs are much broader than the corresponding joints in the other legs. They are also hollowed out and are furnished at the edges with spikelike hairs, which curve inwards over the hollow (Fig. 41). This is on the outside of the leg, and on the inside are several combs, made up of rows of hairs. When the thorax is covered with pollen it is combed out by means of these hairs by the bee crossing its legs beneath its body. The pollen is then fashioned into a little ball or pellet and passed into the pollen basket, where it is held until the bee reaches the hive. Pollen is mixed with honey to make "bee-bread." This is food for the young bees.

FIG. 41.—Pollen basket.

## VII.

Bees belong to the *Hymenoptera* order of insects, and have four wings—a pair of large and a pair of small,

(a)



From photo-micrographs by] (b) [E. Cuzner, F.R.M.S.

SPIRACLES OF *DYTISCUS*

(a) Showing the spiracles on the side of the Water-Beetle. (b) A highly magnified spiracle

called respectively the anterior and the posterior. The name is derived from the Greek words *hymen*, "marriage," and *pteron*, "a wing," and thus means "married wings." The *hymenoptera* are so called because the upper and under wings on each side of the body are "wedded" or linked together when the insect is flying by a row of hooks and a ledge, a device which is more fully explained in the next paragraph. Like the legs, the wings are joined to the thorax; they are composed of fine membranes and are strengthened by a kind of framework. The ribs of this are called the nervures (*a*, Plate XXVII.) and are hollow; like our veins they contain blood.

Along the top edge of the lower wing is a row of tiny hooks, while the lower edge of the upper wing is curled over, forming a kind of ridge (*a*, Plate XXVIII.). There is thus formed a "hook and eye" by which the two wings are locked together for flight (*b*, Plate XXVIII.). By these means a large pair of wings is formed which are more powerful for flying than would be the case if the bee had only two small pairs of wings with no interlocking device. The bluebottle fly has only one pair of large wings, but this arrangement would not be practicable in the case of the bee. If its wings were not divided the worker bee would be unable to crawl into the nursery cells to clean them out. These cells measure $\frac{1}{5}$ inch in diameter. When the wings are folded over the bee's back they take up only $\frac{1}{6}$ inch. There is thus just sufficient space for the bee to enter the cell. The bluebottle does not need to fold its wings closely over its back, for it has no cells to clean.

The action of the hook and eye is almost automatic, for when the bee takes to flight the front wing is stretched out from over its back, and in this operation it passes over the upper surface of the back wing. On the ridge reaching the hooks it catches upon them and is held fast. When the bee comes to rest the process is reversed, for as the wings are folded the ridge slips away from the hooks that hold it.

The number of hooks varies, and sometimes more are found on one side of the body than the other. As a general rule the worker bee has from eighteen to twenty-three. The queen, who seldom flies, has not so many—sometimes as few as thirteen. The drone has large and powerful wings, and the number of his hooks varies between twenty-one and twenty-six.

## VIII.

The abdomen, containing the stomach and intestines, is joined to the thorax by a thin waist. The abdomen of the queen and of the worker is divided into six rings or segments, but the drone, having a somewhat larger body, has seven. Each segment itself is divided into two parts, known as the *scelerites*, and joined to one another by a delicate membrane.

The bee has two stomachs, the honey-sac and the stomach proper. The honey-sac is a kind of store chamber in which the nectar is kept after it has been gathered from the flower, until the bees return to the hive. Leading from it to the stomach is a very fine tube or duct, at the end of which is a kind of stopper or valve, called the "stomach mouth." By opening or closing this the supply of food to the stomach may be regulated. The honey-sac is relatively minute, and even when quite full contains only about one-third of an ordinary sized drop of honey.

The tube which leads from it to the stomach is lined with minute hairs, very fine and pointing in a direction away from the honey-sac. When nectar is taken in from a flower, pollen grains may be unavoidably taken in also. This is undesirable, and so the nectar is passed from the honey-sac to the stomach by means of the tube. The nectar is then made to return to the honey-sac, and in this operation the hairs in the tube act as a strainer and prevent the pollen grains returning with the nectar. This operation is carried on while the bee is flying from flower to flower or on the way back to the hive.

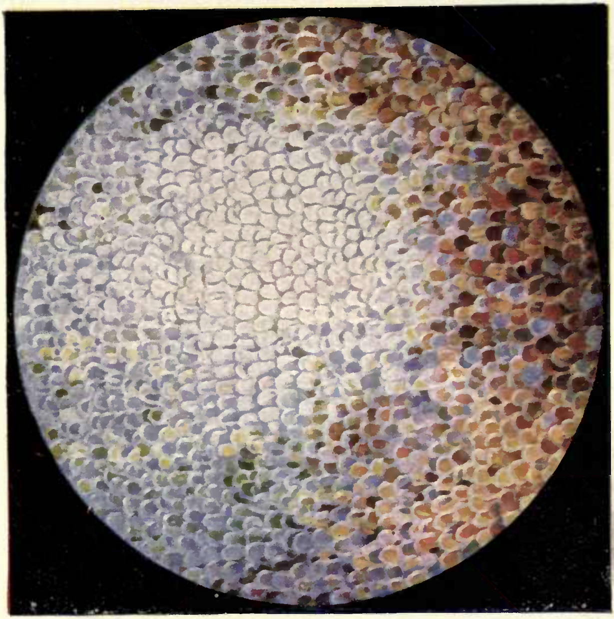
Bees do not actually collect what is called honey, but they gather what the flowers secrete. This is nectar, which may be described as a thin watery liquid, containing among other things a large proportion of cane sugar. The honey-sac is filled with nectar gathered from flower after flower, and while the bee flies a change takes place in the nectar, and it becomes converted into honey. Some juices secreted by glands in the abdomen are added to it and the cane sugar is changed into another form, called grape sugar.

## IX.

Insects breathe through tiny air-holes called "spiracles," from the Latin *spirare*, "to breathe" (Plate XXX.). Crawling insects do not require so much air as flying insects, and their breathing apparatus is therefore not so large. In a bee the breathing tubes spread over almost the whole body, two of the largest extending along each side of the abdomen. These air tubes branch off one from another like the roots of a tree. The majority are exceedingly minute, a bundle of a quarter of a million being required, it is estimated, to equal in size a human hair. The rings of the abdomen slightly overlap one another, and as the bee draws in and then drives out the air, in the act of breathing, these rings constantly slip in and out. The spiracles are protected by a number of tiny hairs which keep out dust and other foreign bodies which would interfere with the breathing.

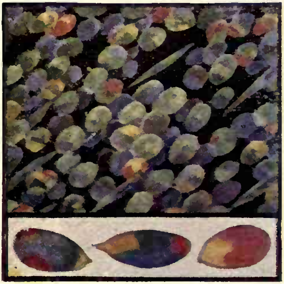
## X.

The sting is situated at the tip of the abdomen and consists of several parts. The sting itself is very smooth and hard, and terminates in a delicate, lance-like point, compared with which an ordinary fine sewing needle looks like a bar of iron (*c*, Plate XXVII.). This sting is really a sheath, in which are enclosed two needle-like darts. On the outside of the sheath at the end are two rows of three, or sometimes more, barbs pointing backwards. These prevent the sheath slipping out of the flesh into which it has been forced, until the operation of stinging is completed. The darts in the sheath can be moved up and down by a powerful set of muscles at the root of the sting. They act like drills, and come into play as soon as the sheath has made an opening for them. They move up and down at a great speed, piercing deeper and deeper into the flesh of the victim each time. They, too, have barbs (*b*, Plate XXVII.), and near each barb is a minute hole leading to a central hollow in the dart.



*a*

b



c

From a water-colour drawing by] [G. Fisher-Jones

(*a*) Part of a Butterfly's wing. (*b*) Scales from the Diamond Beetle.
(*c*) Feather from Humming Bird.

Down this hollow and through the holes in the dart-barbs a poisonous fluid is poured which causes the pain of a sting. The poison is composed largely of formic acid, and is secreted in a poison-bag near the root of the sting (*a*, Plate XXIX.). It is forced down the central hollow of the darts by two muscles acting as pumps. The sting of a worker bee is quite straight, but that of the queen is curved like a scimitar. The drone has no sting.

## CHAPTER XII.

## OTHER INSECTS.

### I.

AS in the case of plants, insects are full of interest to the microscopist; even the most common will reveal points of interest when seen under the microscope, and they will furnish unlimited material for months of study during the long nights of winter. Specimens should be collected during the summer, and may be preserved in weak acetic acid for a very long time, for examination at leisure. They may then be studied just as they are, or if desired may be dissected, their internal organs examined, and further interest added by mounting all the parts on a card, neatly numbering and naming them. Butterflies, spiders, flies, beetles, wasps, fleas, ants, and the like, all are worthy of attention.

There is so much of interest that it is, of course, quite impossible to describe fully even a fraction of the objects. I can only mention a few, and those very briefly, so that you may have an idea of what a wonderful storehouse of interest awaits you.

Insects are sometimes divided into two groups, which are called "friends" and "enemies." This distinction is not, of course, a scientific one, but it may serve as a guide and be of assistance to the memory to know whether a certain insect is helpful or not to us. It is very necessary that we should learn all we can about the habits and life-history of the insects we are studying before classifying them as friends or enemies, because otherwise we might easily make a mistake. For instance, a person who has just been stung by a bee will probably be quite convinced that bees should be included among the "enemy" insects. On the other hand, the bee-keeper will show his hives and dozens of beautifully sealed sections of honey he has obtained from each hive. He will tell you that to say bees should be classed as enemy insects, just because they can sting and hurt, is ridiculous.

Among useful insects may be classed those which fertilize flowers and those which give us honey, silk, dyes, and medicines. In the other group fall the insects which destroy clothing, food, and similar materials, and also those which spread disease. The study of insects, or entomology as it is called, is indeed a fascinating one, and one which presents a very wide field, for in Great Britain alone there are tens of thousands of varieties of insects. It is a study in which there are endless problems, for sometimes the habits of association of the little creatures and the exhibitions of their wonderful instinct seem almost human.

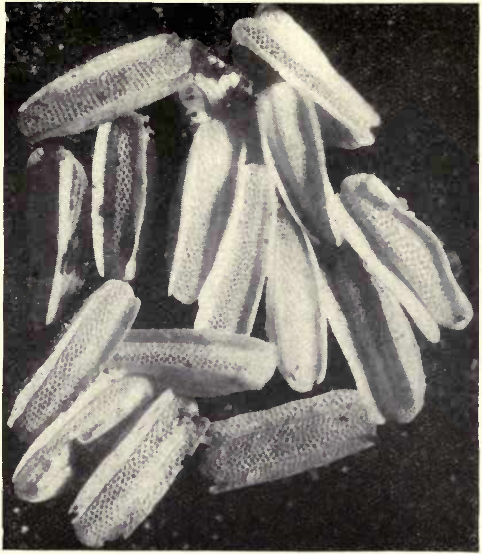
Insects may be classified according to the manner in which they feed—either by biting or sucking—or by the presence or absence of wings. In the latter method the following groups are commonly recognized :—

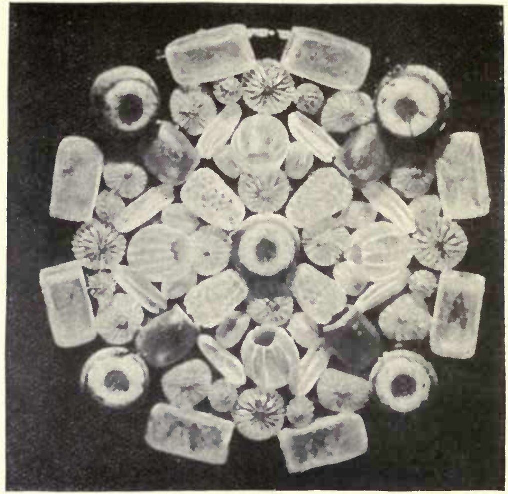
| Classification. | Characteristic. | Example. |
|---|---|---|
| *Aphaniptera* | wingless | Fleas |
| *Coleoptera* | sheath-winged | Beetles |
| *Lepidoptera* | scale-winged | Butterflies |
| *Diptera* | two-winged | Flies |
| *Orthoptera* | straight-winged | Grasshoppers |
| *Neuroptera* | nerve-winged | Dragon-flies |
| *Hymenoptera* | membrane-winged | Bees |
| *Thysanoptera* | tassel-winged | Thrips |
| *Homoptera* | similar-winged | Aphides |
| *Hekeroptera* | dissimilar-winged | Bugs |

## II.

The Drone Fly (*Eristalis tenax*) very closely resembles a bee, and may easily be mistaken for one when on the wing. It has a wonderful foot like a double claw, and with this contrivance it is able to grasp very firmly any object to which it wishes to cling. This is the reason it is called *tenax*, because this word is derived from the Latin meaning "to hold." Its larvæ inhabit filth and mud, devouring garbage and acting as scavengers. In these surroundings breathing is often difficult, so Nature has fitted the larvæ with long, telescopic tails, through which they can breathe.

The tongue of the drone fly is split up a little way, and then again joined, and the mouth parts are converted into lancet-shaped organs. Not only are these darts, with which the skin of animals is pierced, but they also act as tubes through which their blood may be sucked up. Another part of this insect's mouth resembles in appearance a two-edged sword, while yet another has pincer-like cutting teeth at its extremity. It is a peculiar tool and





From photo-micrographs by] [A. E. Smith

(a) (b)

INSECTS' EGGS

(a) Eggs of the House-Fly. (b) Various eggs, grouped

resembles an instrument used by a surgeon to enlarge a wound. It is actually used for this same purpose by the fly, so that the flow of blood may be increased.

## III.

The *Ichneumon* fly helps to keep down caterpillars. The caterpillar pest of 1917 and 1918 was attributed by some naturalists partly to the fact that one cause and another had killed off the *Ichneumon* flies. The caterpillars had thus obtained the upper hand, as it were, and multiplied so profusely as to become a serious menace to fruit-growers and farmers. The *Ichneumon* is equipped with a sharp ovipositor, or egg-laying appendage. With this it pierces the skin of the caterpillar and deposits its minute eggs in the caterpillar's body. It is believed that the caterpillar does not feel the operation, for it will even go on eating while it is being performed. Later the eggs hatch out into tiny grubs which feed on the fatty substances in the caterpillar's body. When the caterpillar has finished eating and is ready to turn into a chrysalis, the young *Ichneumon* grubs leave it and spin themselves bright yellow cocoons. The caterpillar not having any store of fat to draw upon during its chrysalis state, shrivels up and dies from lack of nutriment.

## IV.

Like bees, ants may be either social or solitary insects. That is to say, some species live in colonies, as do bees in a hive, while others live by themselves, like the mason bee, building their own little nests and leading a solitary life. Those ants which live in colonies again resemble bees, there being a queen, males, and workers. The commoner kind are the *Formicidæ*, the queen and males of which sometimes have wings. This causes them to be mistaken by some people for flies. Under the microscope the ant is seen to have two large compound eyes, and three simple eyes in front, like the bee. Some workers are without eyes. The *antennæ* are many jointed, and the jaws sometimes larger than the head itself. Some ants have minute sets of teeth, arranged like the edge of a saw.

## V.

The *aphis*, more commonly known as the "green-fly," which often infests rose-trees, is a curious insect, as seen under the microscope. It is sometimes called the plant lice and has a beak-like mouth. With this it pierces the tender shoots of a plant and sucks up the sap, thus causing the plant to be damaged and sometimes killed. The sap is partly given out again by the insect through two protuberances on its hinder part. Ants know of this fact and they domesticate *aphides*, keeping them as we do cows, for the sake of the sweet fluid they exude. This fluid, called honey-dew, is obtained from the *aphides* by "milking," a process in their case which consists of the ants stroking them tenderly with their *antennæ*.

*Aphides* are reproduced at an alarming rate. It has been calculated that the descendants or progeny of a single *aphis* in one summer will number a quintillion. At this rate the Earth would very soon become a mass of *aphides*, if it were not for the fact that they are food for many other insects. The larvæ of the "lady-bird" eat great quantities of *aphides*, for instance, and this helps to keep the pest in check.

## VI.

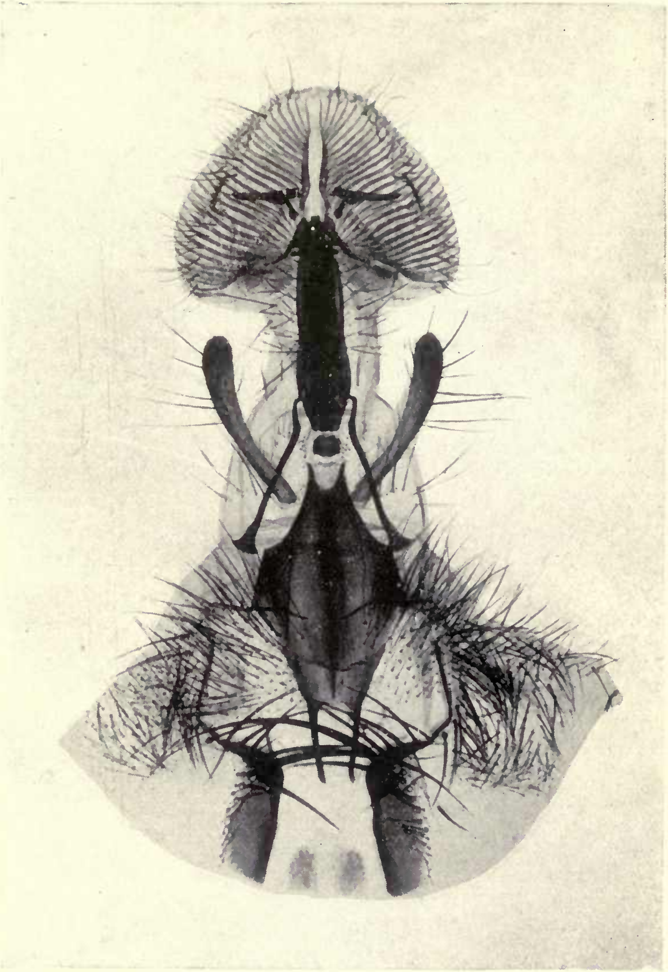
Butterflies and moths are very beautiful objects in the microscope, and among them may be found some of the most lovely sights revealed to us. The colours of their wings, beautiful as they are to the naked eye, are enhanced a hundred-fold even with a low power, and no pen can adequately describe their beauty. The wings are composed of membranes, covered with thousands of tiny scales, and thus it is that these insects belong to the order of *Lepidoptera*, for the word *lepis* means "a scale." These minute scales form the dust which is left on our fingers should we take hold of a butterfly's wing. If a little of this dust be shaken on to a slip of glass and placed under the microscope the scales will be clearly seen. Each scale is held to the wing by a tiny root. The scales lie upon the wing membrane in rows, overlapping each other like the slates on the roof of a house, and they pro tect the delicate membrane against dew and rain.

In *a*, Plate XXXI., is shown a portion about $\frac{1}{16}$ inch diameter of a tiny white dot in the "eye-spot" of the fore-wing of a Peacock butterfly (*Vanessa io*). The scales of butterflies are actually coloured, and therefore differ from the scales of some insects, which are iridescent, or rainbow-hued. To this latter class belong the scales of the small Diamond Beetle (*Curculis imperialis*) shown at *b*, Plate XXXI., which owe their colour to their extreme thinness and their transparency, as in the case of the soap-bubble or oil on water. There is still another class of scales which glow with colour caused by the breaking-up of white light by numerous extremely narrow lines or furrows with which their surface is covered. A very good example of this type is afforded by the minute brilliant feathers in the breast of a Humming Bird (*c*, Plate XXXI.). Those of you who are interested in the explanation of this beautiful iridescent colouring may pursue the matter farther by studying some book on Light, which deals with the interference of light caused by thin films and with diffraction caused by fine surface rulings or striated surfaces.

## VII.

The proboscis or tongue of the butterfly often reaches an enormous length in some species. By its aid the insect is able to reach deep down into the corollas of flowers to extract the nectar secreted there. When not in use the tongue is curled up like the hair-spring of a watch.

We have already seen how flowers are fertilized by insects, and how important it is that the pollen should be carried to the stigma. Much of this work of fertilization is done by bees, but there are some flowers which bees cannot fertilize, owing to the shape of their corollas. Honeysuckle and convolvulus, for instance, have corollas so long that the bee's tongue cannot possibly reach the nectar stored at the base. Flowers such as these depend on butterflies and moths for their fertilization, so we find that these insects are provided with exceptionally long tongues. As moths fly by night, it is then that the flowers which wish to attract them put out their choicest perfumes, for the sweet smell guides the moths to them.



From a photo-micrograph by] [A. E. Smith

THE TONGUE OF A BLOW-FLY

## VIII.

Among the useful insects must be included the silkworm (*Bombyx mori*). No doubt many of you have kept silkworms, and studied their interesting habits. You will therefore know that this insect is not a "worm" at all, but a moth, which, like all moths and butterflies, is first a caterpillar, hatched from a tiny egg. It feeds on leaves and sheds its skin from time to time as it grows, an operation which is made easier by the secretion of an oily fluid between the new and the old skins. When fully grown the caterpillar commences to spin a cocoon of silk. The thread issues from a spinneret and is something similar to the thread of a spider's web. In the silkworm, however, the spinneret is not situated in the abdomen, but in a nipple-like swelling on the caterpillar's lower lip. As the fine thread issues from this spinneret it hardens on exposure to the air. The spinning of the cocoon takes about four or five days, and the amount of thread spun is about 1,000 feet in length. When the silkworm is kept for profit, this thread is subsequently unwound by mechanical means, and is then spun into silk proper. It is estimated that this little insect furnishes employment to over 100,000 people in Great Britain and America alone, while many fortunes have been made—and lost—through it.

## IX.

The eggs of butterflies, moths, and other insects furnish a countless variety of objects for examination. To the naked eye they sometimes appear as greyish spots on the leaves of plants, often occurring in clusters. In the microscope we find them to have a beautiful pearly-white appearance, often delicately coloured, with yellow, green, or red. They are of all manner of shapes and designs (*b*, Plate XXXII.). Some are perfectly smooth, others are fluted and ribbed, sculptured with rims and grooves which run over their entire surface. So distinct are these varieties that a microscopist should easily be able to name the butterfly by seeing its egg. Some butterflies have such beautiful eggs that they are even of more beautiful design than the eggs of birds.

Butterflies' eggs are not surrounded by a shell of carbonate of lime, as are those of birds, but consist of a tough, gelatinous substance which resists strong acids. This so effectively protects the tiny germs within against the elements, that the eggs even may be frozen in a block of ice without killing them. They are thus able to withstand a severe winter and carry over butterfly life to the following spring, the warm days of which hatch out the tiny caterpillars.

Butterflies' eggs, as well as those of moths, are very minute objects. They vary in size from less than $\frac{1}{50}$ inch to $\frac{1}{10}$ inch in diameter. The former would easily drop through a hole made in a piece of paper by a pin. They are generally of two kinds, "upright" and "flat," and may be laid in large batches or singly. They are found in all kinds of places—on bark or twigs of trees in the winter, and in grass or on leaves in the summer. As a rule the mother butterfly takes care to lay the eggs on the leaves of the tree on which the young caterpillar likes best to feed, so that when it hatches out it will have plenty of food ready to hand. Sometimes the tiny caterpillar may be seen inside the egg, which always changes colour and appearance as the time for hatching approaches. A caterpillar may take from five or six days to nine months to hatch out from the egg, according to the particular variety of butterfly or moth to which the insect belongs. Some pass the winter in the egg, but others hatch out in a few days, and in the course of time become butterflies, the whole operation taking place during the same summer in which their mother lived.

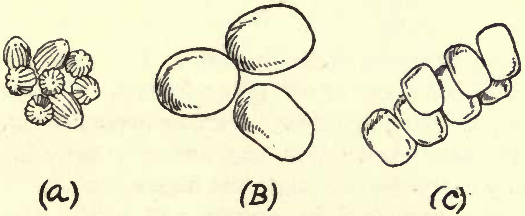



FIG. 42.—Eggs of (*a*) Large White Butterfly. (*b*) Elephant Hawk Moth. (*c*) Scalloped Oak Moth.

The eggs of the Large White Butterfly (*Pieris brassicæ*) are as remarkable as any. They are golden yellow, upright, and have well-defined ribs which run longitudinally (*a*, Fig. 42). They may be found in clusters during June, generally in the leaves of cabbages, and other similar plants, upon which the caterpillar feeds. The eggs of the Painted Lady (*Pyrameis cardui*) are also upright and of a pale green colour. They also have longitudinal ribs, and are formed in June, singly, on thistles and nettles. The eggs of the Elephant Hawk Moth (*Chærocampa elpenor*) are flat and oval-shaped (*b*, Fig. 42). They are green in colour, smooth, and are not decorated at all. They are laid in July on bedstraw, willow-herb, and similar plants, usually those near some stream or pond.

The Scalloped Oak Moth (*Crocallis elinguaria*) lays flat eggs which are oblong and smooth (*c*, Fig. 42). They are brownish white in colour, with patches of dark-brown, and are usually found in straight rows, side by side, along blackthorn twigs. They are laid in July and August, and will not hatch until the following spring.

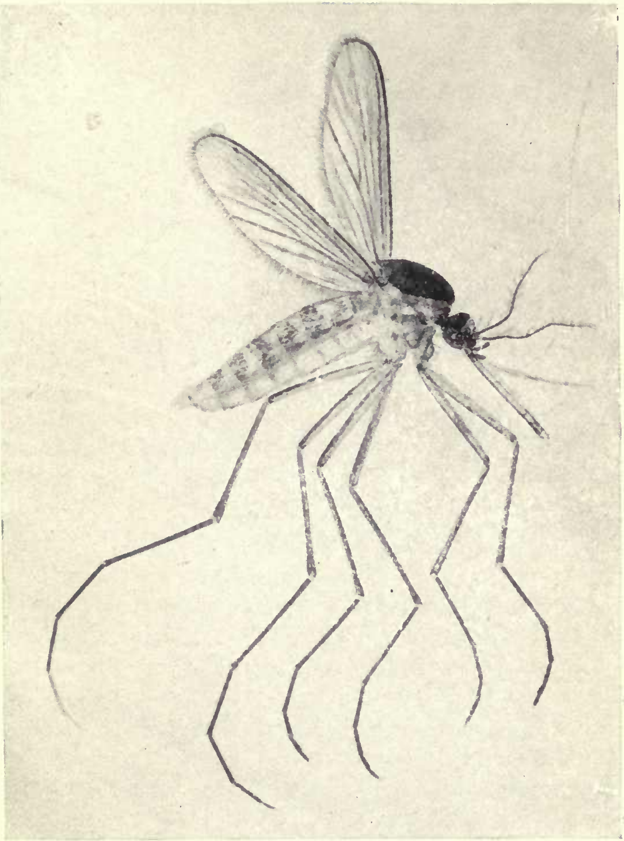
## X.

At one time the house-fly was looked upon by some people as being one of our insect friends, for it acts as a scavenger, eating up refuse. Further investigations more recently have shown that flies are very harmful to us, for they carry disease, and it is because of this that we have been requested by posters and public notices to "kill that fly."

The common house-fly (*Musca domestica*) has one pair of wings, and is therefore classed among the *diptera* or double-winged insects. Its wings consist of a double membrane, strengthened by nervures like those of the bee. It has also two appendages, the halteres or poisers, and these are sometimes called undeveloped or rudimentary wings. They seem to act as balances and enable the fly to walk in difficult circumstances.

The house-fly's tongue is a common object in the microscope, and the proboscis of the blow-fly is a well-known object for testing the quality and defining the power of lenses (Plate XXXIII.). The house-fly's tongue

PLATE XXXIV



From a photo-micrograph by] [A. E. Smith

A GNAT

consists of two parts, the pharynx and the mouth itself. The pharynx is a kind of throat tube which extends beyond the mouth when the fly is feeding, but when not in use it lies in the head. The mouth itself is situated at the end of the pharynx. The proboscis carries numerous hairs of various shapes—well seen in that of the blow-fly—some of which are thicker than others. Those at the end are tubular, and when the tongue is extended in eating, these hairs fill with air and stiffen, thus protecting the delicate parts. When the insect has finished eating and draws in its tongue, the hairs are emptied of air, and become easily movable, so as not to interfere with the folding of the proboscis in the head.

The fly eats in a curious manner. Watch a fly after it has "settled" on some sugar. It first impels its proboscis, and extending it out of its head, causes the two broad fan-like appendages to appear from the top. These act as files and suckers, and with them a little sugar is filed off. The fly then pours some fluid upon this from its mouth organs. This forms a kind of syrup, which is at once sucked up. The tubes of the proboscis are kept open by a spiral arrangement of hair-like fibre, in a similar manner that the garden hose-pipe is kept from bending, or "kinking," by an internal spiral wire. A fly does not bite or sting, as we sometimes suppose, but grates or files with the little tools at the end of its proboscis.

The fly has three pairs of legs, and each is divided into five parts. The tarsus, or foot, is fitted with two formidable claws, also a delicate pad, carrying many tubular hairs, and covered with a sticky fluid. This enables the foot to adhere to slippery objects, and the fly is thus able to walk up a pane of glass or similar smooth surface.

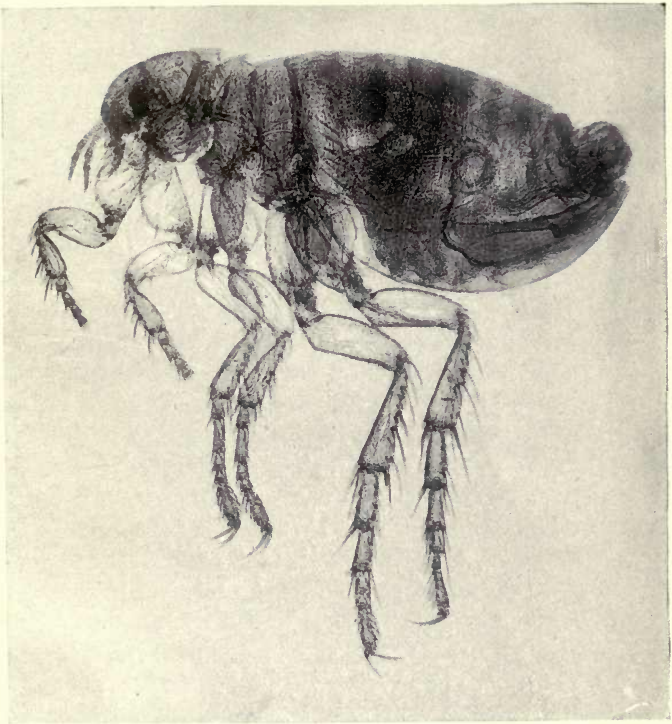
The fly has a comparatively large "heart," or dorsal vessel, as it is called, which beats. The blood flows through the fly's body in the reverse way to that of ours, being forced by the contraction of the heart from tail to head.

When we speak of insects having blood, we do not mean blood similar to that of human beings any more than we mean their dorsal vessel is a true heart. The blood of insects is transparent, nearly colourless, and differs in other respects from our blood. It is kept pure by aeration by *tracheæ,* which, as we have already seen, are air-tubes running through the insect's body.

Flies are to a certain extent of use in the economy of nature, for they consume decaying matter that would not otherwise be removed, and which in hot weather would perhaps harbour disease. Linnæus, a celebrated naturalist, said that three flies would consume a dead horse as quickly as a lion. He meant, of course, these flies and their offspring. It has since been said that the saying is probably quite correct, since the young begin to eat as soon as they are hatched, and a female blow-fly will produce 20,000 living larvæ. In twenty-four hours each will have increased in weight 200 times, in five days attaining their full size, changing to the pupæ, and then to the perfect insect.

Although flies are, beyond doubt, of some value as scavengers, they are the cause of much trouble in other ways. The house-fly may carry germs of disease upon

PLATE XXXV



From a photo-micrograph by] [A. E. Smith

A FLEA

its feet and proboscis and, by its dirty method of eating—already described—transfer these to human food. The larvæ of the Bott fly, or "horse-fly," often bore into the skin of sheep and cause these animals great irritation and pain, which sometimes results in death. The *Tse-tse* fly is the carrier of the organisms which cause the dreaded sleeping sickness in Africa and the tropics.

## XI.

The gnat (Plate XXXIV.) has very graceful *antennæ*, and indeed, as we might well expect, it shows very delicate structures when magnified. The male gnat has plumed *antennæ*, which are marked by their lightness and grace. As in the case of the bee, the gnat's *antennæ* consist of many joints, generally about fourteen, and from each of these spring hairs. In the case of the male, these hairs are very numerous and of great length, thus giving the plumed appearance already mentioned.

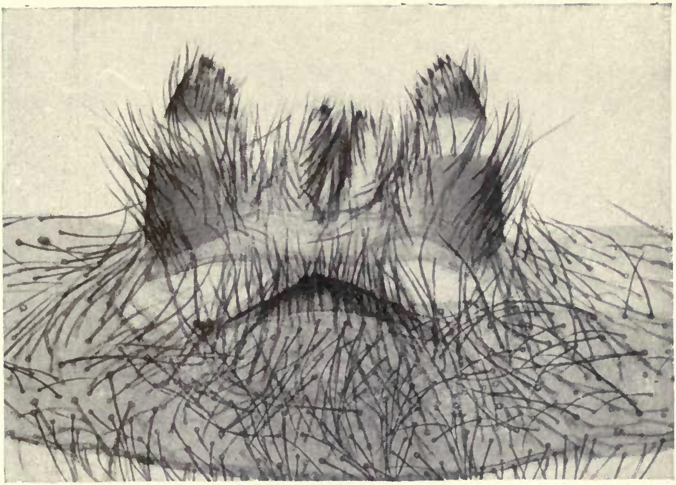
Gnat-grubs may be obtained in the summer from almost any water-tub or pond, for they swarm on the surface of the water. These grubs are partly transparent, and through the outer covering may be seen the flat, rounded head, the great swollen thorax, and finally the long, slender, many-jointed body. The head shows a pair of rod-like *antennæ*, two black patches marking the place of the eyes-to-be, and the jaws, covered with rows of strong hairs and ever working with rapid vibrations. The thorax is so transparent that—as in the case of *Daphnia*—we may watch the gnat's heart, or dorsal vessel, as we should call it, beating and pulsating with beautiful regularity. Sometimes we may discern a dark pellet of food descending through the "throat," and this explains the constant vibrations of the jaws, which collect the food from the water in minute particles and form it into a pellet to be passed into the stomach when sufficiently large. All these may be seen if the grub is young enough, for then the tissues of the outer covering are beautifully transparent and resemble amber. As the insect grows older, however, the tissues become opaque and the fine details cannot be made out.

To a certain extent the wings of the gnat resemble those of the bee. Two transparent membranes are strengthened by nervures. Both sides are covered with numerous and minute short spine-like hairs, while along the nervures and outer edges of the wings are set long hair-like scales. When one of these scales is examined with a high power it is seen to be a leaf-shaped plate of transparent substance and of curious appearance.

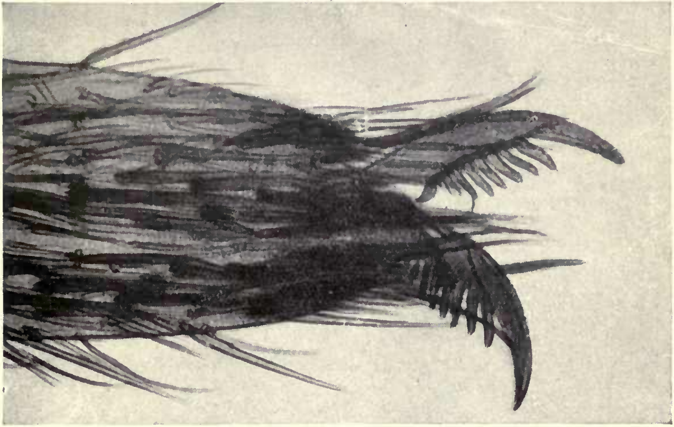
## XII.

Another common insect—rightly classed among the "enemies"—is the flea (Plate XXXV.). This was a favourite object for examination and show purposes with early microscopists. The flea does not "bite," although its attentions are so-called. In its mouth-part is a fine, sharp piercing organ like a lancet. With this it pricks the skin of its victim and sucks out the blood. The irritation is caused by the flea injecting into the wound a drop of poisonous liquid, by which the blood of the victim becomes more fluid and thus is more easily sucked up.

PLATE XXXVI



(a)



From photo-micrographs by] (b) [C. D. Holmes

(a) SPINNERETS OF THE SPIDER. (b) SPIDER'S CLAW

## XIII.

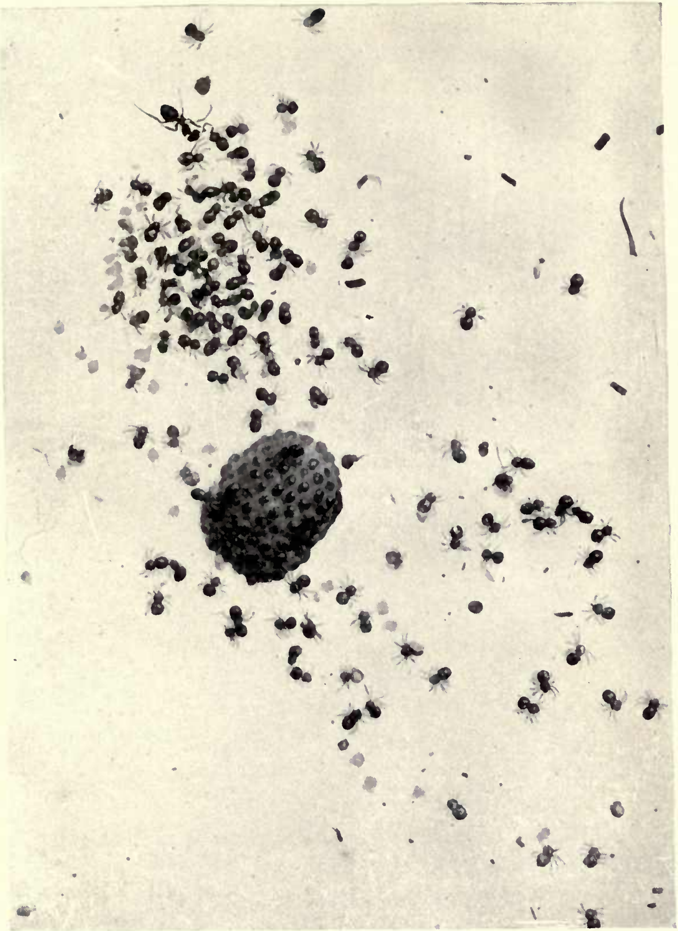
Mites and ticks are not insects, but are really associated with spiders. As they are "fleas" to animals and insects, however, we may perhaps say a word or two about them here. In the perfect state they resemble spiders in the number of their legs, eight. Sometimes they are found with only six legs, sometimes with even only four, but when found thus they are in an immature state. Some find their food in plants or decaying matter, but others are parasites.

The *Gramasidæ*, or insect-mites, are perhaps the best known. They may be found on beetles, flies, bees, and other insects. They cling to the bodies of their hosts, and a hand lens will often show their struggles in the downy hairs which cover the bee's body.

Mites are also found in fresh and salt water, in the latter case on seaweed in rock pools. Fresh-water mites are often partly coloured with red or purple and have an appearance like velvet. At the tip of their feelers, or palpi, they have a tiny hook, and with this they hook themselves to marine creatures. Over twenty species of fresh-water mites have been discovered in ponds in England alone. Mites may also be obtained from hanging hams or flour which has been kept in a bin for any length of time. The cheese mite (*Acarus domesticus*) is well known, and examples may be obtained from cheese which has been kept a long time.

Ticks are somewhat larger than mites, are oval in shape, and have a sucking mouth. Some are blind, but others have eyes. They live on herbage, as a rule.

The female sometimes causes a great deal of trouble by piercing the skin of some warm-blooded animal and sucking its blood. Much pain and suffering is thus caused to cattle. Sometimes when walking in the fields you may have seen a starling pecking away in a curious way at the fleece of some sheep. These birds are really feeding upon the sheep's ticks entangled in the wool. The sheep goes on eating its grass while the operation is in progress, well pleased no doubt at the efforts of these birds to free it from the painful pest. The sheep tick, however, is an insect, and not really a tick. It has only six legs, and is placed among the lower flies—*diptera*—although it has no wings. It is thought that the sheep tick is a descendant of some higher type of insect, and that probably it has become a parasite owing to its remote ancestors acquiring the habit of feeding themselves at the expense of other animals. Becoming too lazy to seek its food by hard work, it obtained it easily and without much effort in the manner already indicated. Now, Nature has decreed that faculties which remain inactive and are not wanted shall be done away with. Thus, seeing that the sheep tick did not use its wings, they have gradually disappeared, with the result that the sheep tick of to-day has none. Not only is it absolutely dependent upon its host, therefore, but also it cannot fly away from the starling and the crow, which pick it out of the sheep's tangled wool.



From a photograph by] [W. Coles-Finch

YOUNG SPIDERS HATCHING OUT

## CHAPTER XIII.

## MINIATURE ENGINEERS: SPIDERS.

### I.

THE spider, with its wonderful power of designing and spinning webs, may indeed be called a miniature engineer. Never was a gulf bridged more effectively with iron and steel than is the space between branches or leaves by the web of the spider. There is, however, an important distinction between the two bridges, for whereas that of human beings is used for traffic, the web of the spider is a trap or snare by which the little blood-sucker obtains its food.

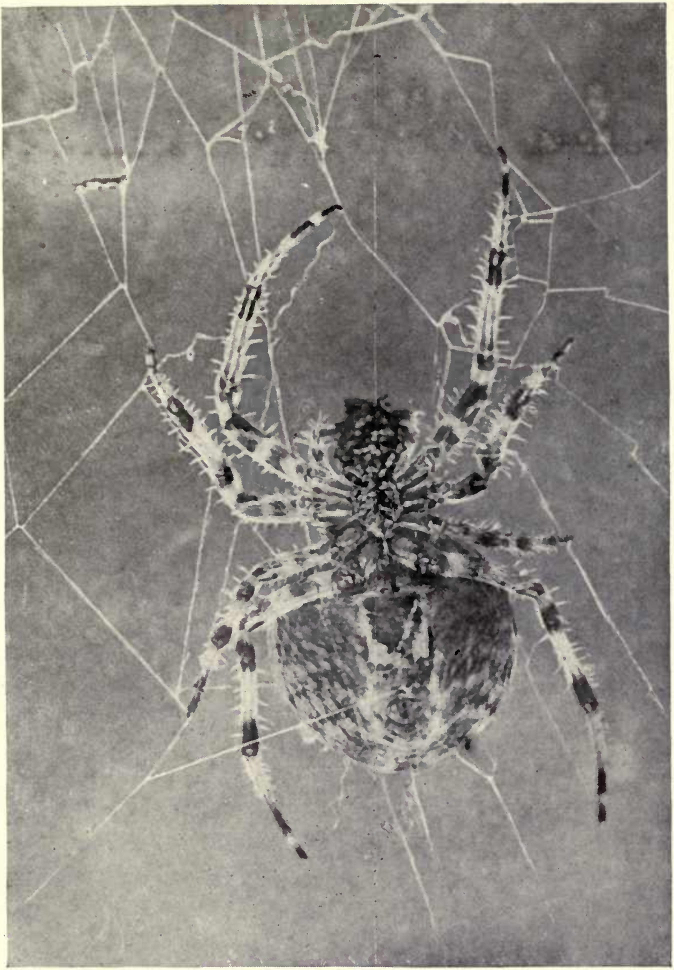
The name "spider" is derived from the old English word *spinder*, "a spinner." You have no doubt heard some people speak of spiders as insects, but this is not scientifically correct. They belong to a sub-class of *Anthropoda*, called *Arachnidæ*, and are related to scorpions and mites. They come between crustaceans—like the lobsters—and true insects in their classification. It is useful to remember that the highest forms of crustaceans have ten feet, *Arachnidæ* eight, and insects six. Also that *Arachnidæ* have several simple eyes, are as a rule wingless, have no *antennæ*, and breathe by tracheal tubes and sacs. They are mostly carnivorous, or flesh-eating, and because they live on insects they may be regarded as friends by the gardener, for they destroy many pests which might otherwise damage fruit and flowers. They also help to keep down what would otherwise assuredly be a plague of flies, for the whole tribe of spiders are fly-butchers by profession. Just as our butchers have their slaughter-houses, knives, pole-axes, and hooks, so these little slaughterers have their nets, traps, and caves, their fangs, hooks, and poison bags. "No one," wrote Professor Rymer Jones, "who looks at the armament of a spider's jaws can mistake the intention with which this terrible apparatus was planned. 'Murder' is engraved on every piece that enters into his composition."

There are about 2,500 known species of spiders, of which some 550 are to be found in the United Kingdom. Many of them make most interesting pets and grow quite tame. No doubt you have read of the poor prisoner in the Bastille who whiled away the long hours of his captivity by taming a spider which occupied his dungeon with him.

## II.

The spider's body is made up of three parts, the head, thorax, and abdomen, but the head and thorax are almost merged into one. As in the case of insects the legs are attached to the thorax, and are so placed as to allow great freedom of motion. The abdomen is of large size, especially in female spiders, and is often beautifully coloured and decorated with peculiar designs. Especially

PLATE XXXVIII



From a photograph by] [W. Coles-Finch

GARDEN SPIDER REPAIRING WEB

is this so in the case of the upper surface, where the markings are like mosaic, and often take the form of a cross. The legs are covered with stout bristles and are provided with claws, of which we shall speak later.

The majority of spiders have very small mouths, and can therefore consume only liquid food, which they suck from their prey. In most cases spiders capture this prey by spinning webs, and it is because they spin these webs that the class to which they belong is called *Arachnidæ*. Arachne was a Lydian maiden, so skilful in needlework that she challenged Minerva, the goddess of the art, to a trial of skill. Although Arachne's hand-work was exquisite, Minerva's was even more beautiful. In despair at her work being surpassed Arachne hanged herself, but was changed into a spider by the goddess. When we see the beautiful work of the spider, it is interesting to recall this old Greek legend.

## III.

It is the spinning of these webs and the apparatus for this work which is the most interesting part of the spider's anatomy to the microscopist. The spinning organs of these spiders which construct circular webs are the most complicated.

The gossamer threads of which the webs are composed are among the finest lines in creation. They issue from the spinnerets, which are small teat-like swellings in the under side of the abdomen (*a*, Plate XXXVI.). Their position is well seen in Plate XXXVIII., in which is depicted a female garden spider repairing her damaged web, at the same time holding a fly in her mandibles.

These spinnerets vary in number in different spiders, some having four, others six. Sometimes, but not often, there may be as few as two or as many as eight. In those spiders which have six spinnerets we have to look carefully for the extra two, as sometimes it would seem as though there are only four. The spider can move the spinnerets as it wishes, raising or lowering them, and using one, many, or all of them, as it requires. Each spinneret consists of a large number of silk tubes, which in the common garden spider amount to 600. There are also different kinds of spinning glands, and in this same spider these are five in number. The silk of each of these glands differs in nature, and is skilfully employed as required by the spider. For instance, some of the larger tubes in the teats give out a more sticky fluid than the others. They are all combined to form one thread, as various strands of hemp are combined to form a rope, except that the spider's strands are not twisted in the way that a rope is.

Nearly all spiders encase their eggs in a cocoon of silken thread, and store them in a sheltered place. Here they pass through the cold days of winter and await the coming of spring and warm weather, which will hatch out the young spiders. In the case of the Wolf Spider, the female always carries the cocoon containing the eggs with her, and vigorously resists any attempt to separate her from it.

## IV.

The spider does not undergo metamorphosis, or "change of form," like many insects, such as butterflies and bees,

PLATE XXXIX

From a photograph by] [W. Coles-Finch

WEB OF GARDEN SPIDER COVERED WITH DEW

which are first eggs and then become grubs, before they finally assume the perfect state of the fully developed insect. Spiders resemble the cockroach and grasshopper, assuming the adult form as soon as hatched, and thus developing direct from an egg to a spider. The female spider lays her eggs in the early autumn, producing perhaps 200 or 300 in quick succession. She rolls them into a kind of ball with her legs, encircles them with a thick covering of web, and deposits them in some sheltered position. You may often find one of these nests in some garden wall or fence, looking like a large chrysalis of a pale yellow colour. Sometimes it is covered with dirt and leaves which match the surroundings. These the spider has woven into the outer layers for protection, for the cocoon is a delicate morsel for hungry birds at a time of the year when food is scarce. When the spring comes, the eggs hatch and myriads of tiny spiders are to be seen—in some cases no larger than a pin's head—all busily occupied in exercising their legs as well as their silken surroundings will allow (Plate XXXVII.). These soon commence housekeeping on their own account, as the numerous webs on surrounding plants and bushes testify.

## V.

One of the best-known spiders is the Garden Spider, already mentioned (Plate XXXVIII.). Its scientific name is *Epeira diademata*, and it is the largest variety found in this country. It may easily be recognized by the white and yellow spots with which its body is covered, and the dark bands and spines on its long legs. Its body is usually some shade of brown or grey, although sometimes it may be vivid green, or even, chameleon-like, change colour with its surroundings.

It has four pair of eyes arranged in two rows; the male is much smaller than the female and is often in danger of his life, especially after paying his attentions to the female, for she frequently makes a meal of him! If he is wise the male spider will leave a line of web hanging near by when he goes a-courting. He can then rapidly escape from the side of the female if she attempts to eat him, and as the hanging line is not strong enough to bear the weight of the female the male will escape if he is quick enough. Sometimes both male and female will live together in quite a friendly manner. One particular pair I know of shared the same geranium leaf day after day, huddling close together during the nights in the same web.

The Garden Spider spins the beautiful geometrical web which looks so exquisite in the early morning when covered with thousands of dewdrops (Plate XXXIX.). When spinning its web, the spider first lays the foundations, or the

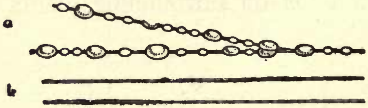



FIG. 43.—Threads of spider's web. (*a*) Trapping lines. (*b*) Web lines.

"spokes" of the wheel-design. These consist of a strong and simple double thread, which hardens rapidly by exposure to the air (*b*, Fig. 43). Then, lying across this scaffolding, are placed the circular threads like the main-

From a photograph by] [J. Holmes

TRANSPARENT NEST OF WATER SPIDER

spring of a watch. These threads are covered with a sticky fluid from the larger tubes, and in the microscope look like a thread strung with minute beads (*a*, Fig. 43). It has been estimated that as many as 120,000 of these globules are contained in a large web.

## VI.

Spiders spin their webs as traps in which to catch flies and other insects which they require for food. Sometimes a web may be completely spun in forty-five minutes, or it may occupy as long as four or five hours. When it is finished, *Epeira* will wait in the centre of the web, or concealed close by in a den of leaves. If the latter is the case she will generally lay a trap line from the hub, or centre of the web, to her den, by means of which she can instantly tell when a fly has touched the snare. Spiders are largely dependent upon their sense of touch for information as to what takes place in their web.

A spider has eight legs, each curiously constructed and terminating in a strong, horny claw, having the appearance of a small comb (*b*, Plate XXXVI.). The teeth of this comb are set close together and enable the spider to obtain a firm foothold in its web, and thus she is able to walk easily on a single strand. Her feet not only regulate the issue of the silken threads and separate them, but also they are sensitive to an exquisite degree. It is by resting them on the trap line, already mentioned, that the spider is able to feel when a fly has entered her web.

It is believed that a spider resorts to a practice known as "trolling the fly." She attaches a strand to her victim, already helplessly entangled in the meshes of her web, and turns the fly round and round like a joint on a spit. By these means the fly is soon completely entangled in the silken strand and is left trussed up, hanging like a ham from the ceiling of a farmhouse. If a wasp or heavy insect blunders into the web, the spider is out at once, drawing long threads around her struggling prey from a safe distance. Once the prey is bound, it is soon inflicted with a bite from the spider's poison fangs, and its doom is sealed.

The water spider (*Argyroneta aquatica*) is an extremely interesting pet, which can be kept in an aquarium. It builds a dome-shaped nest, something like a thimble, below the surface of the water (Plate XL.). This is a curious habit, for the spider is only fitted out for air-breathing. She overcomes the difficulty, however, by carrying down to the nest each time she dives a bubble of air which becomes entangled in the hairs of her body. To see her carrying down the silver bubbles, and filling her nest with air, converting it into a tiny diving bell, is indeed a fascinating sight.

Space forbids my describing any more of the wonders of spiderland, but if you wish to do so, you can learn for yourself of the wonderful instinct of the mother spider for her young, of the industry of spiders, of the ballooning spiders, of the wonderful cave-dwellers, and of the cunning of the trap-door spider.

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