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1938



COMMON OBJECTS OF THE  
MICROSCOPE



# COMMON OBJECTS OF THE MICROSCOPE

*By the late*

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*Author of*

“COMMON OBJECTS OF THE COUNTRY”

“COMMON OBJECTS OF THE SEASHORE”

*Revised and Re-written by*

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## PUBLISHER'S NOTE

THE main purpose of this guide to the elementary study of microscopy is to reveal to the readers the great variety of objects that can be easily obtained and examined with absorbing interest. Many who are now enthusiastic users of the microscope in all its branches are only too willing to admit that they owe their introduction to the science through one of the earlier editions of this present work. The original author possessed the gift of translating the researches of the scientific into the language of everyday life and an endeavour has been made to keep this purpose in view in revising for this edition.

We are indebted to Messrs. W. Watson & Sons, Ltd., for the loan of the diagrams illustrating the various microscopes and accessory apparatus.



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COMMON OBJECTS OF THE  
MICROSCOPE



## CHAPTER I

A Pleasant Recreation—Discoveries made by Amateurs—An Unlimited Field for Study—Expensive Apparatus Unnecessary.

THE microscope has now become an essential tool in all branches of science and technology. In the early stages of its invention, when in form it was primitive, the wonders revealed amazed everyone—even the learned. Any available object was used for examination and much discussion went on, as was only natural, in the attempt to explain what was seen.

With the passing of the years, the microscope, by constant usage, has developed into the instrument of precision we know to-day, and one adaptable to suit any specialized subject.

The testing of materials used in the manufacture of aircraft, internal combustion engines, bridges, steel fittings—the examination of the human body for the causative agents of disease—the constant investigation of foodstuffs to detect signs of impurity, and many other similar cases readily called to mind, all involve the use of the microscope.

We are not, however, concerned in these pages with such advanced and serious work. Rather we take the view that the microscope can be a pleasant method of improving the mind and a means towards spending many an hour in harmless amusement.

It is an established fact that the examination of the common objects, that are available anywhere, is a delightful hobby and has attracted an ever-increasing band of devoted amateurs. New discoveries are constantly being made and the number of problems that still remain to be solved, as for instance in regard to the life histories of many of the small inhabitants of ponds and ditches, are so many that even the merest beginner may stumble on something that may be of vital importance towards this end.

As one instance of the significance of the microscope as a scientific instrument, Sir Ronald Ross—the discoverer of the malarial germ—spent countless hours looking down the tube of his microscope, searching, probing, and dissecting the bodies of mosquitoes until he found what he was seeking. His researches have meant that the life history of the germ in relation to man and mosquito has become fully known, and further, by identifying the insect and taking measures to destroy it, large tracts of land have become safer for colonists. It was only by destroying the breeding places of the mosquito, carrier of the Yellow Fever germ, that that immense engineering feat, the Panama Canal, was made possible. Until then shipload after shipload of labourers had to be sent to take the place of those who were ill. So from this brief example it can be gathered how important the microscope is in making the initial discovery which later has a direct bearing on the progress of civilization.

In the following chapters we propose to carry out, as far as possible with reference to the microscope, the system followed in the *Common Objects of the*

*Country and Common Objects of the Seashore*, and to treat, in as simple a manner as may be, of the marvellous things which nature has provided, and found so profusely in our fields, woods, streams, shores, and gardens. Moreover, our observations will be restricted to an instrument that can be easily handled and of an inexpensive make. We will also describe the various odds and ends of "gadgets" useful for special subjects, keeping in mind always articles of a moderate cost.

The descriptions will be given in language as simple and as free from technical terms as is possible. But it must be remembered that there are no popular names for some structures and organisms, therefore we shall have to describe such by their scientific names. As this little book is intended to be a stepping-stone to those of a more learned nature, it is far better for the beginner to know the various plants and animals described by their proper names than in simplified terms which they will have to unlearn later. It will be our purpose to use correct terms, and explain them, as far as necessary, as we introduce them.

The beginner is strongly recommended, after he has worked through the sections, to adopt one branch for study and observation. Through specialization, greater opportunities are offered for discovery and original work. Try to work out a plan, the following out of which will have better results than any general and purposeless distribution of effort. For instance, the student of pond-life will find new organisms awaiting description by the hundred. Many diatoms will furnish opportunities for study.

The smaller fungi will amply repay the closest examination of their habits of life as so many of them are the cause of disease in plants ; the cycle of development is obscure in some species and unknown in others. In fact there is scarcely any group of organisms which will not yield something to careful investigation. There is little doubt, therefore, that any worker even with a simple instrument, but with an observant eye, studying one of the commonest plants or most familiar insects cannot fail to accomplish something which will add to the credit of the observer.

Although it is beyond the scope of this work to treat of the refined and costly apparatus which is essential to useful work in certain departments of research, modern methods of manufacture have resulted in conditions very favourable to the worker of moderate means and ambitions, since lenses are accessible now from a few shillings and upwards. Some readers may have to make some of the accessory pieces of apparatus which are described in the next chapter because they cannot afford to purchase at first hand. They will find pleasure and occupation in so doing. For encouragement let it be emphasized that many home-made appliances fulfil their purpose just as well as the highly ornate and complicated apparatus of the wealthier amateur. It is not the man who possesses the finest or most costly apparatus, but the one who best understands the use of that which he has, who will make the most successful microscopist. Secrets of nature which have escaped the notice of many can be discovered, by a good observer, with only the aid of a pocket

magnifier. It is for such that this book has been written, and in the following pages many hints will be given whereby the true observer can be guided in his search for knowledge.

Those of an historical turn of mind will be reminded that an enormous amount of excellent and valuable work was done in the early days when the microscope was being developed. Some of the instruments were beautifully made and highly decorated, although the essential part often contained but a single lens! The painstaking work that was accomplished with such limited means is truly amazing and therefore an example to the beginner to-day, who has at his disposal apparatus of much better quality.

## CHAPTER II

Elementary Principles of Optics—Simple Microscopes—Compound Microscopes—Accessory Apparatus—Cover-glasses—Troughs—Condensers—Dissection—Dipping-tubes.

BEFORE attempting to deal with the microscope itself, it may be useful to give a short summary of the optical laws upon which its working depends.

To go deeply into the matter here would be out of place, but it will be found very helpful, especially in the matter of illumination, to acquire some knowledge of, and facility in applying, these elementary principles. We shall confine our remarks to convex lenses, as being the form to which all the combinations in the microscope may be ultimately reduced.

Every convex lens has one "principal" focus, and an infinite number of "conjugate" foci. The principal focus is the distance at which it brings together in one point the rays which fall upon it parallel to its axis, as shown in Fig. 1, in which  $A$  is the axis of the lens  $L$ , and the rays  $RR$  are brought together in the principal focus  $P$ . Thus a ready means of finding the focal length of any lens is to see at what distance it forms an image of the sun, or of any other distant object, upon a screen, such as a piece of smooth white cardboard. In the figure this distance will be  $PL$ . Conversely, if the source of light be at  $P$ , a parallel beam of light will be emitted from the lens.

The focal length may, however, be found in another way. When an object is placed at a distance from a lens equal to twice the principal focal length of the latter, an image of the object is formed at the same distance upon the other side of the lens, inverted in position, but of the same dimensions as the original object. The object and image then occupy the equal conjugate foci of the lens, so that by causing them to assume these relative positions, and halving

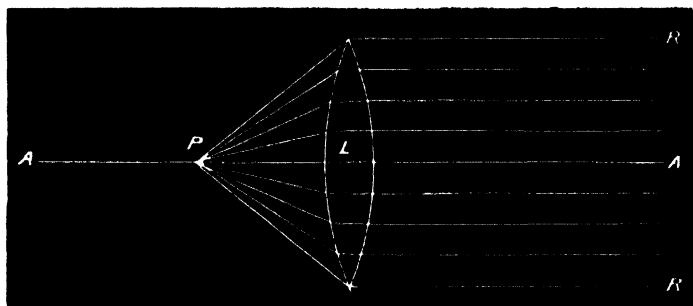


FIG. 1.

the distance at which either of them is from the lens, the focal length of the latter is known.

These points will be seen on reference to Fig. 2, in which  $L$  being the lens, and  $P$  the principal focus, as before, rays from the point  $C$  are brought together at the conjugate focus  $C'$ , at the same distance on the other side of  $L$ . In this case it is immaterial whether the object be at one or the other of these points.

So far we have been dealing with points on the line of the axis of the lens. The facts mentioned apply equally, however, to rays entering the lens at

an angle to the axis, only that in this case they diverge or converge, correspondingly, upon the other side. It is evident, from Fig. 1, that no image is formed of a point situated at the distance of the principal focus; but Fig. 3, which is really an extension of Fig. 2, shows how the rays passing along secondary axes form an inverted image of the same size as the object, when the latter is situated at twice the focal length of the lens from this last.

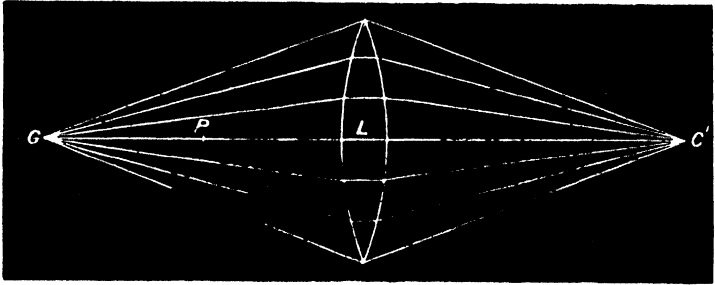


FIG. 2.

To avoid confusion, the limiting lines only are shown, but similar lines might be drawn from each and every point of the object; and if the lines  $ALA'$ ,  $BL'B'$  be supposed to be balanced at  $L$  and  $L'$  respectively, they will indicate the points at which the corresponding parts of the object and image will be situated along the lines  $AB$ ,  $B'A'$  respectively. Moreover, rays pass from every part of the object to every part of the lens, so that we must imagine the cones  $LAL'$ ,  $LA'L'$  to be filled with rays diverging on one side of the lens and converging on the other.

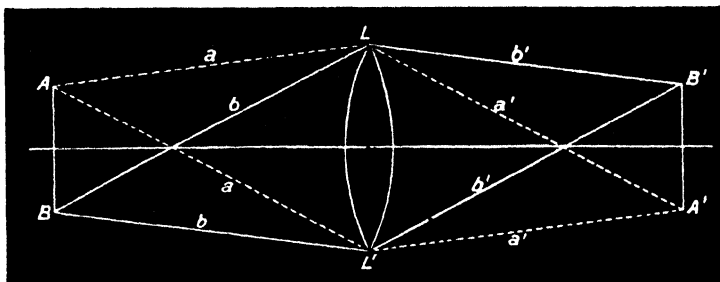


FIG. 3.

The image so formed is a "real" image—that is to say, it can be thrown upon a screen.

The microscopic image, on the other hand, is a virtual image, which can be viewed by the eye but cannot be thus projected, for it is formed by an object placed nearer to the lens than the principal focal length of the latter, so that the rays diverge, instead of converging, as they leave the lens, and the eye looks, as it were, back along the path in which the

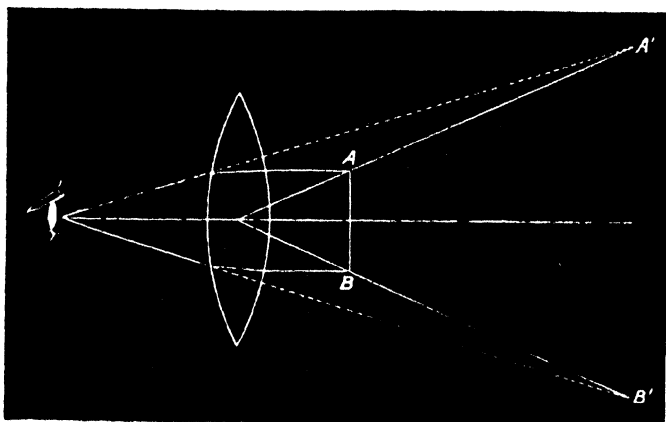


FIG. 4.

rays appear to travel, and so sees an enlarged image situated in the air, farther away than the object, as shown in Fig. 4. In this case, as the diagram shows, the image is upright, not inverted.

Images of the latter class are those formed by simple microscopes, of the kind described as pocket lens. In the compound microscope the initial image, formed by the object-glass, is further magnified by another set of lenses, forming the eye-piece, by which the diverging rays of the virtual image are brought together to a focus at the eye-point. When viewed directly, the eye sees an imaginary image, as in a simple microscope, whilst, when the rays are allowed to fall upon a screen, they form a real image of the object, larger or smaller, as the screen is farther from or nearer to the eye-point.

These remarks must suffice for our present purpose. Those who would know more about the elementary principles of optics as affecting the microscope are advised to consult some such work as *An Introduction to the Theory and Use of the Microscope*, by C. R. Marshall and H. D. Griffith. Most books of an elementary nature dealing with physics will contain useful notes in the sections on light.

In following a work such as the present one, the simple microscope, in some form or other, will be found almost indispensable. It will be required for examining raw material, such as leaves or other parts of plants, for gatherings of life in fresh or salt water, for dissections. With such powers as those with which we shall have to deal, it will rarely happen that, for example, a bottle of water in which no life is visible will be worth the carrying home ;

whilst, on the other hand, a few months' practice will render it not only possible, but easy, to recognize the forms of life present. Moreover, these low powers, affording a general view of the object, allow the relation to each other of the details revealed by the power of the compound microscope to be much more easily grasped. A rough example may illustrate this. A penny is a sufficiently evident object to the naked eye, but it will require a sharp one to follow the details in Britannia's shield, whilst the minute scratches upon the surface would be invisible in detail without optical aid. It would be rash, however, to conclude from an examination of a portion of the surface with the microscope alone that the portion in view was a sample of the whole surface. The more the surface is magnified, the less are the details grasped as a whole, and for this reason the observer is strongly recommended to make out all that he can of an object with a simple magnifier before resorting to the microscope.

For general purposes the observer cannot do better than supply himself with a common pocket-magnifier, with one, two, or, preferably, three lenses, as although the absolute performance is not so accurate, the range of power available by using the lenses singly, or in various combinations, is of great advantage.

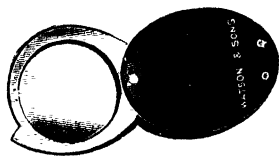


FIG. 5.

Such a magnifier (Fig. 5) of the best quality, in a folding case, may be obtained for about twelve shillings and sixpence; single lenses in horn or vulcanite mounts are readily found from eighteen

pence and upwards. Aplanatic or platyscopic lenses are much more costly, but they give a large and flat field of vision, and are therefore unsurpassed as pocket-lenses. The illustrations (Figs. 6 and 7) show

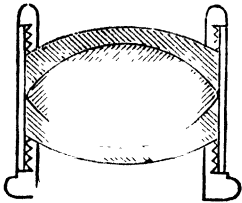


FIG. 6.

how the magnifier is made of three lenses cemented together, and how the whole is mounted and protected when carried in the pocket.

So much for the simple microscope. We pass on now to the consideration of the instrument which forms the subject of the present work, a microscope which, moderate in price, is yet capable of performing a large amount of useful and accurate work in the hands of a careful owner.

The student's microscope, as illustrated by the frontispiece, is of standard pattern which has been designed for all-round purposes. This model has a rack and pinion coarse adjustment with a fine adjustment fitting which can be operated from either side.

The foot is of the modified horseshoe type, very rigid, and the limb is curved—an

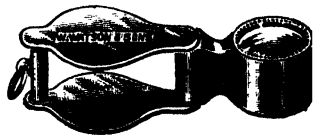


FIG. 7.

advantage when handling the instrument. Though this microscope is not very expensive, perhaps one of a cheaper type is more suitable for most readers of this book.

We have, therefore, selected as our example a simple but efficient instrument that fulfils all the essential requirements of the beginner. It has been

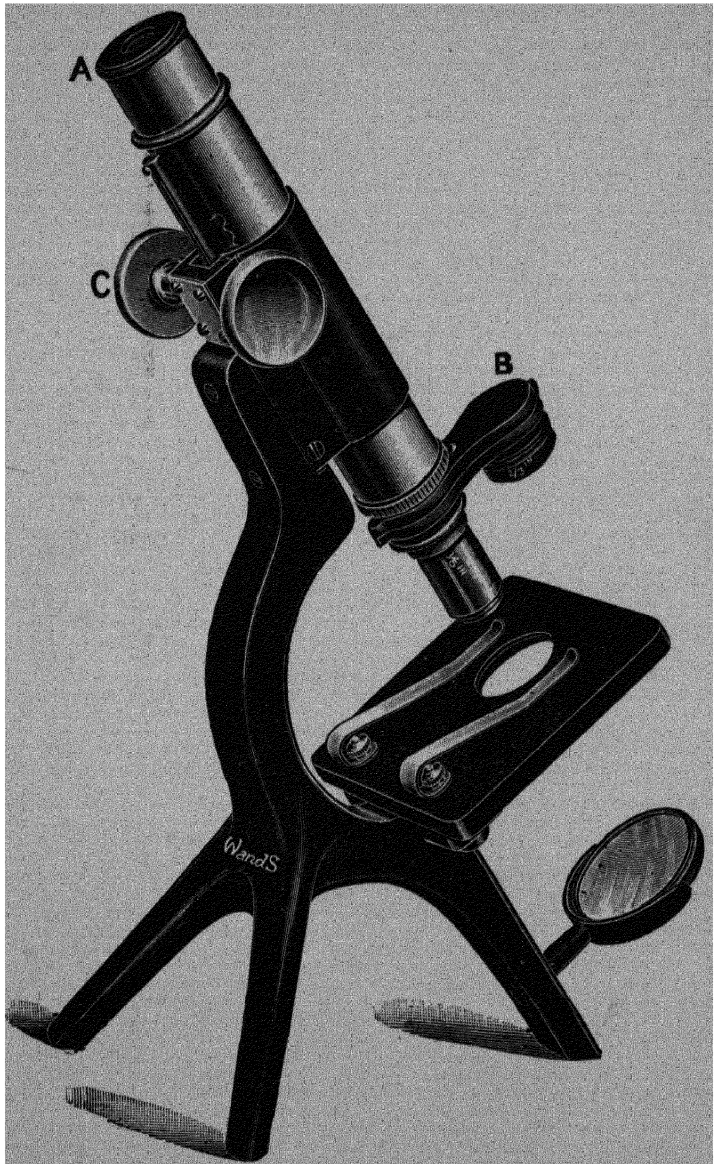


FIG. 8.

constructed by a firm of manufacturers with many years' experience of the more elaborate types of microscope. All parts are of fine quality and of standard size, which is a point most amateurs overlook when making their first choice. The advantage is obvious in that one can add extra lenses and fittings from time to time as the owner can afford to purchase them.

There are one or two unusual characteristics in this model (Fig. 8) which overcome some of the drawbacks of the average cheap instrument. The



FIG. 9.

first is that the stand, or main structure, is constructed of one piece and set at an angle most useful for comfort in ordinary examination. Perfect rigidity is thus ensured—a very necessary condition. The next special point is in the means of adjusting the focusing. The body which carries the eye-piece and objective lenses is moved up and down by turning the wheels (C) seen near the top of the stand, but as a means of finer adjustment is important, the makers have suggested moving the eye-piece (A) in or out as required, by gently turning (not sliding), which will give a rapid but accurate result. For this purpose, when inserting the eye-piece (Fig. 9) do not place it flush with the top of the tube, allow a short distance for making the fine adjustment afterwards.

The stage is fitted with the usual springs which enable the object, live-box, etc., to be held there and adjusted for position. Underneath is a simple fitting (Fig. 10) designed to hold a magnifier (Fig. 11)

which can be used as a substage condenser, an invaluable accessory even in this simple form.

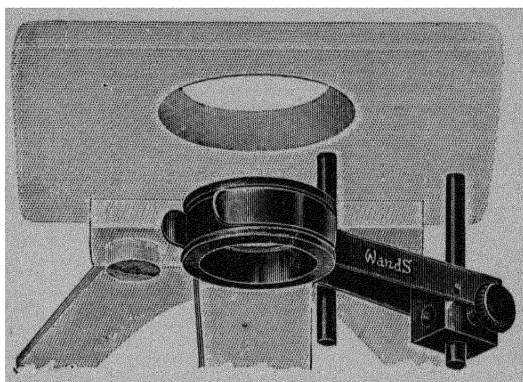


FIG. 10.

The same fitting will also take a polarizer (Fig. 12) and with its complementary part the analyser, placed between the objective and nose-piece of the instrument, will make possible the joys of examining

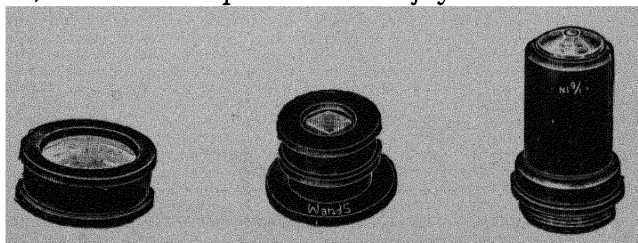


FIG. 11.

FIG. 12.

FIG. 13.

objects by polarized light described more fully in Chapter X.

The lenses are made to standard formulæ and the beginner is recommended with this instrument to purchase two low-power objectives, one a  $1\frac{1}{2}$  in.

and the other a  $\frac{2}{3}$  in. ; for more advanced work later on, a power of  $\frac{1}{6}$  in. (Fig. 13), is available.

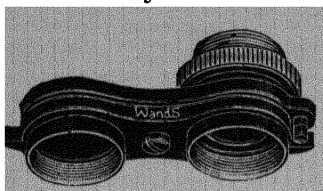


FIG. 14.

A very useful attachment is the double nose-piece (Fig. 14) which is screwed into the lower end of the tube and enables the objectives to be quickly interchanged when a higher magnification is needed.

Of accessory apparatus, we may mention first the stage forceps (Fig. 15). These are made to fit into one of the holes in the stage after the spring clips have been removed. They can be turned about in any direction, with an object in their grasp, and

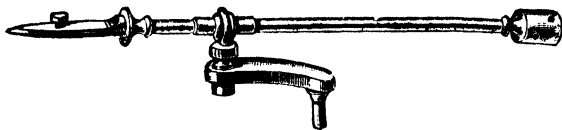


FIG. 15.

for some purposes, especially the examination of a thin object like the edge of a leaf, are very useful indeed.

The live-box, in which drops of water or portions of water-weeds may be examined, will be found of great service. By adjustment of the sleeve to which is attached the cover-glass, with proper attention to the amount of pressure applied, living organisms can be studied with ease. The illustration (Fig. 16) gives a cross section view of this apparatus which is attached to the stage by means of the spring clips

as in the ordinary way of using a glass slide. In examining delicate objects, such as the larger infusoria, in order to preserve their symmetry under the pressure, it is a good plan to restrict their movements by placing a few threads of cotton-wool, well pulled out, in the live-box with the drop of water.

A few glass slips and cover-glasses will also be required; glass slips are quite cheap, the standard size  $3 \times 1$  inches being 5d. a dozen. Cover-glasses are sold by the ounce, varying in price from 2s. 9d. to 5s. 6d., according to their size and shape. The beginner had better start with the cheaper kind as



FIG. 16.

it will be found difficult to clean the thinner and more expensive type without a large percentage of fractures. The safest way in cleaning is to boil them in dilute nitric acid (half acid, half water) for a few minutes, wash well in several waters, first tap-water and then distilled, and finally to place the covers in methylated spirit. When required for use, the spirit may be burnt off by applying a light, the cover-glass, held in a pair of forceps, being in no way injured by the process.

In addition to the glass slides, the observer will find it advisable to be provided with a few glass troughs (Fig. 17), of various thicknesses, in which portions of water plants, having organisms attached

to them, may be examined. Confined in the live-box, many of the organisms ordinarily found under such circumstances can rarely be induced to unfold their beauties, whilst in the comparative freedom of the trough they do so readily. The troughs may be purchased for a few pence or may be made of any desired shape or size by cutting strips of glass of a thickness corresponding to the depth desired, cementing these to a glass slide somewhat larger

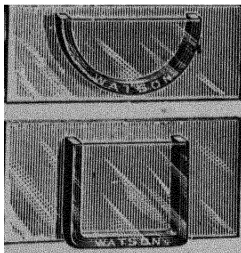


FIG. 17.

than the ordinary pattern, and cementing over the frame so formed a piece of thin glass. A useful practical hint in the use of such troughs is that the corners, at the top, should be greased slightly, otherwise the water finds its way out by capillary attraction, to the detriment of the stage of the microscope.

Of optical accessories, the bull's-eye is most valuable. This is a large plano-convex lens mounted in an adjustable stand, and much may be effected by its proper use in practised hands. It is well worth the while of the beginner to master its use thoroughly, and the methods of doing so will be explained in the succeeding chapter.

Many plants and animals require to be dissected to a certain extent before the details of their structure can be made out, and for this purpose the naked eye alone will rarely serve. The ordinary pocket magnifier, however, if mounted in a small stand, will greatly facilitate matters, and the light may be focused on the object by means of the

bull's-eye. A type of apparatus (Fig. 18) on these lines known as a dissecting low-power microscope can be purchased ; it is very useful and well worth the extra expenditure.

As all delicate structures are dissected under fluid, a shallow dish is required. For this purpose nothing is better than one of the dishes used for developing photographic negatives. The bottom of the dish should have a piece of flat cork, cut to fit

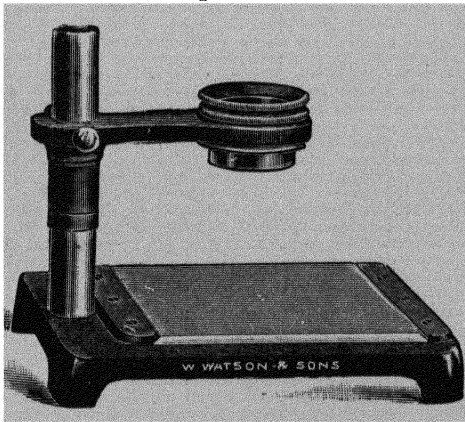


FIG. 18.

tightly, and the object having been pinned to the cork in the required position, the fluid is carefully run in. This fluid will naturally vary according to the results desired to be obtained, but it must not be plain water, which so alters cellular structures as to practically make them unrecognizable under the microscope. Nothing could be better than a 5 per cent solution of formalin, were it not for the somewhat irritating odour of this fluid, since it at once fixes the cells and preserves the figure. For many

purposes a solution of salt, in the proportion of a saltspoonful of the latter to a pint of water, will answer well for short dissections. For more prolonged ones, a mixture of spirit and water, one part of the former to two of the latter, answers well, especially for vegetable structures.

When the dissection in either of these media is completed, spirit should be gradually added to bring the strength up to 50 per cent, in which the preparation may remain for a day or two, after which it is

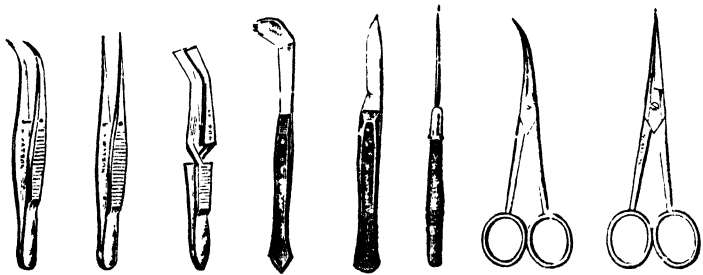


FIG. 19.

gradually brought into pure spirit, or into water again, according to the medium in which it is to be mounted.

As to the tools required, they are neither numerous nor expensive. Fine-pointed but strong forceps (Fig. 19), curved and straight; a couple of pairs of scissors, one strong and straight, the other more delicate, and having curved blades, and a few needles of various thicknesses and curves, are the chief ones. The latter may be made by inserting ordinary needles, for three-fourths of their length, into wooden penholders. Dipping tubes will also be useful for many

purposes. These are very easily made by heating the centre of a piece of glass tubing of the required size, and, when it is quite red-hot, drawing the ends apart. The fine tube in the centre should now be divided by scratching it with a fine triangular file, and the scratch may, of course, be made at such a point as to afford a tube of the required fineness. The edges should be smoothed by holding them in the flame until they just run (not melt, or the tube will close). These tubes can often be made to supply the place of a glass syringe. They may be used either for sucking up fluid or for transferring it, by placing the finger over the wide end, allowing the tube to fill by displacement of air, and then reclosing it with the finger. This last method is useful when small objects are to be removed from one receptacle to another, such as from a bottle of pond-water to the trough or live-box.

After using any piece of accessory apparatus it should be thoroughly cleaned and put away under cover. The same remark applies to the microscope itself—stains from fluid and dust need careful removal—the lenses being wiped with a piece of silk. Never wipe lenses with any odd piece of cloth that happens to be handy or much damage will be done to the highly polished surfaces. Care and cleanliness must be kept to the fore in all operations with the microscope.

## CHAPTER III

Examination of Objects—Principles of Illumination—Mirror and its Action—Substage Condenser—Use of the Bull's-eye—Opaque Objects—Photo-micrography.

So much depends upon a right method of employing the microscope, as regards both comfort and accuracy, that we propose to devote a little space to the consideration of the subject.

Let us first warn the observer against the use of powers higher than are required to bring out the details of the object. Mere magnification is of very little use: it increases the difficulties both of illumination and of manipulation, and, as already said, interferes with that grasp of the object which it is most desirable to obtain. Rather let the beginner lay himself out to get the very most he can out of his lowest powers, and he will find that, by so doing, he will be able far better to avail himself of the higher ones when their use is indispensable.

The essential means to this end is a mastery of the principles of illumination. For all ordinary purposes a paraffin lamp will be the most convenient, with a half-inch flat wick, and we will now describe how it is used.

We suppose the microscope to be inclined at an angle of about  $70^\circ$  to the horizontal, with a low-power objective attached. Opposite to the microscope, and about a foot away from it, is the lamp

with the edge of the flame presented to the microscope, the concave mirror of which is so arranged as to receive the rays from the flame and direct them up the tube of the microscope. Upon the stage is placed a piece of ground-glass, and the mirror-arm is now to be moved up or down upon its support until the ground-glass receives the maximum of illumination, which it will do when the lamp-flame is at one conjugate focus of the mirror and the ground-glass at the other. The focus will not be an image of the flame, but a bar of light.

If an object be now placed upon the stage, instead of the ground-glass, and the objective focused upon it, it will, if the mirror be properly adjusted, be brilliantly illuminated.

It will be understood that every concave mirror has a focus, and converges the rays which fall upon it to this focus, behaving exactly like a convex lens. The principal focus of a concave mirror is its radius of curvature, and this is not difficult to determine. Place side by side a deep cardboard box and the lamp, so that the concave mirror may send the rays back, along a path only slightly inclined to that by which they reached it, to the bottom of the box. The lamp and box being equidistant from the mirror, it is evident that when the mirror forms an image of the former upon the latter equal to the flame in size, we have the equivalent of the equal conjugate foci shown in Fig. 2. Now move the box to the distance from the mirror which corresponds to the distance of the stage of the microscope from the mirror when the latter is in position upon the microscope, and then move the lamp to or fro until the mirror casts a

sharp image of the flame upon the bottom of the box, which is not to be moved. The lamp distance so found will be the correct one for working with the concave mirror. The writer is led to lay special stress upon this matter, from the fact that he almost invariably finds that the mirror is arranged to be used for parallel rays, *i.e.* for daylight, and is therefore fixed far too close to the stage to be available for correct or advantageous working with the lamp, unless, indeed, the bull's-eye condenser be used, as hereinafter described, to parallelize the rays from the lamp.

Work done with the concave mirror can, however, under the most favourable conditions, only be looked upon as a makeshift. The advantages gained by the use of a substage condenser, even the most simple, in conjunction with the plane mirror, or even without any mirror at all, are so many that the beginner is strongly urged to provide himself with some form or other of it, and we now proceed to describe the way in which this should be used to produce the best effect.

To reduce the problem to its most simple elements, turn the mirror altogether out of the way, and place the microscope upon a block at such a height as shall be convenient for observation, and shall allow the rays from the lamp, placed in a line with it on the table, to shine directly into the tube of the microscope. Ascertain that this is so by removing both objective and eye-piece and looking down the tube, when the flame should be seen in the centre, edgewise. Now replace the eye-piece, and screw on to the tube the objective. Place upon the stage an object, preferably a round diatom or an echinus-spine, and focus

it as sharply as possible. Now place the substage condenser in its jacket, and slide it up and down until the image of the object is bisected by the image of the flame.

The centre of the object will now be brilliantly illuminated by rays travelling in the proper direction for yielding the best results. The object is situated at the common focus of the microscope and the condenser, and, whatever means of illumination be adopted, this is the result which should always be aimed at.

Satisfactory as this critical arrangement is, however, from a scientific point of view, it has its drawbacks from an artistic and æsthetic one. It is not pleasant, for most purposes, to have merely the centre of an object lighted up, and we have now to consider how the image of the edge of the flame may be so expanded as to fill the field without sacrificing more than a very small fraction of the accuracy of the arrangement just attained.

Referring to Fig. 1, we see that if we place the lamp at the principal focus of a lens, it will emit a bundle of parallel rays equal in diameter to the diameter of the lens. This is the key of the position. We cannot place the lamp at an infinite distance from the substage condenser, but we can supply the latter with rays approximately parallel, so that it shall bring them to a focus upon the object at very nearly its own principal focus. This we do by means of the bull's-eye condenser. Place the latter, with its flat side toward the edge of the flame, and at its principal focal distance (the method of determining which has already been described) from the

latter, so that the bundle of parallel rays which issue from it may pass up to the substage condenser. On examining the object again, it will be found that, after slight adjustments of the position of the bull's-eye have been made, the object lies in the centre of an evenly and brilliantly lighted field.

It may be necessary to place the bull's-eye a little farther from or nearer to the lamp, or to move it a little to one side or the other, but when it is at the correct distance, and on the central line between the lamp and the substage condenser, at right angles to this line, the effects will be as described. It may help in securing this result if we mention that when the bull's-eye is too far from the lamp, the image of the flame is a spindle-shaped one ; whilst, when the distance between the two is too short, i.e. less than the principal focal length of the lens, the field is crossed by a bar of light, the ends of which are joined by a ring, whilst on either side of the bar there is a semicircular dark space.

We have hitherto supposed the objects viewed to be transparent, but there are many, of great interest, which are opaque, and call for other means of illumination. Of these there are several. The simplest and, in many ways, the best, is to use the bull's-eye condenser to bring to a focus upon the object the rays of light from some source placed above the stage of the microscope. If light can be obtained from the sun itself, no lens will be needed to concentrate it ; and indeed, if this were done, there would be considerable risk of burning the object. The light from a white cloud, however, with the help of the bull's-eye, answers admirably.

At night-time an artificial source of light, the more intense and the more distant the better, is required. For most cases, and with low-power objectives, the paraffin lamp placed about two feet away from the stage, and on one side of it, so as to be a foot above the level of the object, will give you all that is needed. Electric lamps may be used, but the ordinary plain type is useless. A special lamp of inexpensive make (Fig. 20) can be purchased which has a gas-filled globe, the glass having a suitably grained surface to diffuse the light.

Lieberkuhn's condensers are useful aids, but are somewhat expensive. They are concave mirrors, which are so adjusted to the objective that the latter and the reflector come into focus together, the light being sent in from below, or from one side.

One other method of illumination must be mentioned before leaving the topic, and this is the illumination of objects upon a "dark field." With suitable subjects, and when carefully managed, there is no method which gives more beautiful effects, and it has the great advantage of allowing the object to be brilliantly lighted, without the strain to the eyes which is involved in such lighting by the usual method of direct illumination.

It consists essentially in allowing the light to fall upon the object from below, at such an angle

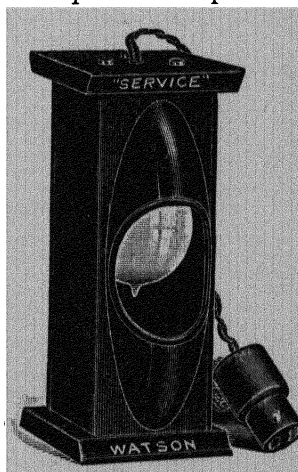


FIG. 20.

that none of it can enter the objective directly. Thus the concave mirror, turned as far as possible to one side, and reflecting on to the object the rays from the lamp placed upon the opposite side, will give very fair results with low powers ; this plan, however, is capable of but very limited application. Again, a disc of black paper may be stuck on to the middle of the bull's-eye, and the latter be placed below the stage between it and the mirror. In this case everything depends upon the size of the disc, which, if too small, will not give a black ground, and if too large will cut off all light from the object.

The best and only really satisfactory plan is to arrange the illumination with the substage condenser, as previously described, and then to place below the lens of the latter a central stop of a suitable size, which can only be determined by trial. When this has been done the object will be seen brilliantly illuminated upon a field of velvety blackness. Such stops are supplied with the condenser.

We have devoted a considerable portion of space to this question, since it is, of all others, the most important to a successful, satisfactory, and reliable manipulation of the microscope ; but even now, only the main points of the subject have been touched upon, and the worker will find it necessary to supplement the information given by actual experiment. A few failures, rightly considered, will be valuable experience, and with patience, industry, and a little thought the beginner will make steady progress.

Most beginners, at one time or another, having a beautiful object of outstanding quality, feel they

would like to have a permanent record. The application of the camera to the microscope is advantageous towards this end as few are sufficiently skilled in drawing to get a good result. It is, moreover, very effective to illustrate one's notes with photographs, the exact reproduction of the structure described being much better than badly drawn and crude sketches.

A lengthy reference to this topic here is out of place because the hobby of photo-micrography is really a separate study. However, a few words may be useful in guiding the reader. In the first place, the bare essentials are, a microscope with a steady stand, a good illuminant, a camera of "landscape" pattern, and the usual photographic dishes and chemicals. In this simple form, the apparatus should be fitted up horizontally and attached to a board. Very little experiment will show how the microscope can be attached to the camera and the object focused so as to appear with all details sharply defined on the ground-glass screen. If the eye-piece of the microscope and the lens of the camera are removed, the tube of the instrument can be attached by a velvet sleeve to the lens-board of the camera. An hour or so spent in experiment will be fruitful in producing results.

For those who can afford to purchase additional apparatus for the microscope, the two following photo-micrographic attachments are mentioned.

The simplest means yet devised of taking a permanent photographic record is undoubtedly the eye-piece camera (Fig. 21). With this the eye-piece is withdrawn from the microscope and the

camera attachment inserted in the tube in its place. The object is then viewed through the tube seen on the left of the illustration, and by moving the fine adjustment the object is focused on the photographic plate. The shutter is then adjusted for

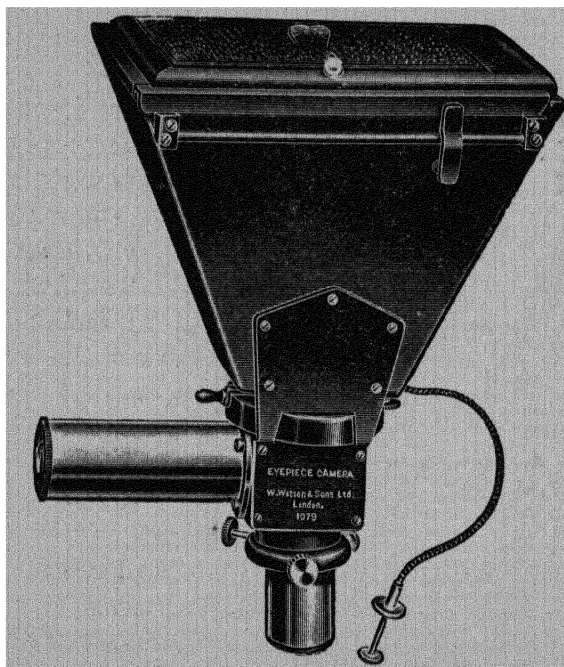


FIG. 21.

time or "snap" exposure, and the rest of the procedure is the same as in ordinary photography.

A more elaborate apparatus is the vertical photomicrographic camera. As can be seen by Fig. 22, the camera is erected on a heavy metal stand. When making preliminary preparations with the microscope, the camera is swung on one side, but when

ready for photographing is swung back again, the light-excluding connections made, and the image focused on the ground-glass screen. By means of the extending bellows a wide range of magnification is made possible.

When using any type of photo-micrographic apparatus it is essential to have a solid foundation where it is not subjected to vibration. The ideal situation is on a good strong bench placed in the basement of a building. Good work cannot be done with, for instance, a rickety bench erected on the top floor of a tall house situated near a main road. This is in reference to low power work, as it affects the beginner, which necessitates long exposures.

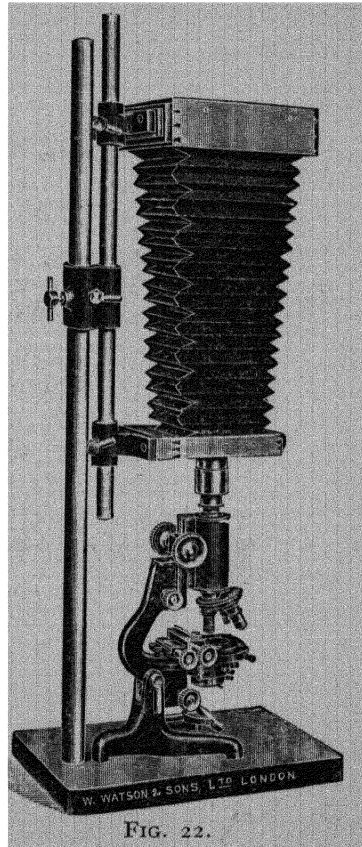


FIG. 22.

## CHAPTER IV

A Simple Vegetable Cell—The Many Shapes of Cell Structures—Ducts and Vessels—How a Plant Breathes—The Protective Power of Hairs—Fragrant Scents and Oils—How they are Stored.

HAVING now obtained a suitable microscope, and from a study of the preceding pages gained some degree of expertness in the use of the various parts, the beginner will be only too anxious to get to work.

Interesting objects that can be used in the study of microscopy are abundant, but unless some method is used, it is possible to be so bewildered that the whole thing is given up in despair. The best plan by far is to follow out some systematic study of the plants, insects, etc., similar to that adopted in this book. With a few exceptions, which are given for illustrating some special aspect, all the objects herein described are obtainable without difficulty. After working through these pages, the beginner may find that one section will perhaps have a particular attraction, and he can then develop this interest to the best advantage.

These words of advice are written from experience of the difficulties which the earlier stages of this entrancing hobby have in store for the would-be microscopist, when without a guide through the maze of natural history.

The objects that can be most easily obtained are

those of a vegetable nature, as even in London there is not a square, an old wall, a greenhouse, a florist's window, or even a greengrocer's shop, that will not afford an endless supply of material. Even the humble vegetables that make their daily appearance on the dinner-table are highly interesting; and in a crumb of potato or a fragment of carrot the enthusiastic observer will find occupation for many hours.

Following the best examples, we will commence at the beginning, and see how the vegetable structure is built up of tiny particles, technically called "cells."

That the various portions of every vegetable should be referred to the simple cell is a matter of some surprise to one who has had no opportunity of examining the vegetable structure, and indeed it does seem more than remarkable that the tough, coarse bark, the hard wood, the soft pith, the green leaves, the delicate flowers, the almost invisible hairs, and the pulpy fruit, should all start from the same point, and owe their origin to the simple vegetable cell. This, however, is the case; and by means of a few objects chosen from different portions of the vegetable kingdom, we shall obtain some definite idea of this curious phenomenon.

On Plate I, Fig. 1, may be seen three cells of a somewhat globular form, taken from the common strawberry. Anyone wishing to see these cells for himself may readily do so by cutting a very thin slice from the fruit, placing it on a glass slide, covering it with one of the thin cover-glasses and examining with the aid of a  $\frac{2}{3}$  in. objective. Should the slice be rather too thick, it may be placed in

the live-box and well squeezed, when the cells will exhibit their forms very distinctly. In their primary form the cells seem to be spherical ; but as in many cases they are pressed together, and in others are formed simply by the process of subdivision, the spherical form is not very often seen. The strawberry, being a soft and pulpy fruit, permits the cells to assume a tolerably regular form, and they consequently are more or less globular.

Where the cells are of nearly equal size, and are subjected to equal pressure in every direction, they force each other into twelve-sided figures, having the appearance under the microscope of flat six-sided forms. Fig. 8, in the same Plate, taken from the stem of a lily, is a good example of this form of cell, and many others may be found in various familiar objects.

We must here pause for a moment to define a cell before we proceed further.

The cell is a closed compartment, the outer walls of which are composed of an elastic membrane (like a gelatine capsule), mainly composed of a substance called " cellulose." Inside is a semi-liquid material, the " protoplasm " and other matter forming the basic life-giving power of the plant. This is constantly on the move and embedded in it will be seen a " nucleus " (Fig. 1), and this again is dotted with one or more " nucleoli," but will need a high-power magnification to distinguish with certainty.

On the same Plate (Fig. 2) is a pretty group of cells taken from the internal layer of the buttercup leaf, and chosen because they exhibit the series of tiny and brilliant green dots to which the colour

of the leaf is due. The technical name for this substance is "chlorophyll," or "leaf-green," and it may always be found thus dotted in the leaves of different plants, the dots being variable in size, number, and arrangement. A very fine object for the exhibition of this point is the leaf of *Anacharis*, the "Canadian timber-weed," to be found in almost every brook and river. The leaf should be placed in the live-box with a few drops of water which, if warmed slightly to promote movement of the cell contents, will show admirably the circulation of the protoplasm.

In the centre of the same Plate (Fig. 12) is a group of cells from the pith of the elder-tree. This specimen is notable for the number of little "pits" which may be seen scattered across the walls of the cells, and which resemble holes when placed under the microscope. In order to test the truth of this appearance, the specimen was coloured blue by the action of iodine and dilute sulphuric acid, when it was found that the blue tint spread over the pits as well as the cell-walls, showing that the membrane is continuous over the pits.

Fig. 7 exhibits another form of cell, taken from the *Sparganium*, or bur-reed. These cells are tolerably equal in size, and have assumed a square shape. They are obtained from the lower part of the leaf. The reader who has any knowledge of entomology will not fail to observe the similarity in form between the six-sided and square cells of plants and the hexagonal and square facets of the compound eyes of insects and crustaceans. In a future page these will be separately described.

Sometimes the cells take most singular and unexpected shapes, several examples of which will be briefly noticed.

In certain loosely made tissues, such as are found in the rushes and similar plants, the walls of the cells grow very irregularly, so that they push out a number of arms which meet each other in every direction, and assume the peculiar form which is termed "stellate," or star-shaped tissue. Fig. 3 shows a specimen of stellate tissue taken from the seed-coat of the privet, and rather deeply coloured, exhibiting clearly the beautiful manner in which the arms of the various stars meet each other. A smaller group of stellate cells taken from the stem of a large rush, and exemplifying the peculiarities of the structure, are seen in Fig. 4.

You will at once see that this mode of formation leaves a vast number of interstices, and gives great strength with little expenditure of material. In water-plants, such as the reeds, this property is extremely valuable, as they must be greatly lighter than the water in which they live and at the same time must be endowed with considerable strength in order to resist its pressure.

A less marked example of stellate tissue is given in Fig. 11, where the cells are extremely irregular in their form, and do not coalesce throughout. This specimen is taken from the pithy part of a bulrush. There are very many other plants from which the stellate cells may be obtained, among which the orange affords very good examples, in the so-called "white" that lies under the yellow rind, a section of which may be made

with a very sharp razor, and placed under the microscope.

Looking toward the bottom of the Plate, and referring to Fig. 27, the reader will observe a series of nine elongated cells, placed end to end, and dotted profusely with chlorophyll. These are obtained from the stalk of the common chickweed. Another example of the elongated cell is seen in Fig. 14, which is a magnified representation of the rootlets of wheat. Here the cells will be seen set end to end, and each containing its nucleus. On the left hand of the rootlet (Fig. 13) is a group of cells taken from the lowest part of the stem of a wheat plant which had been watered with a solution of carmine, and had taken up a considerable amount of the colouring substance.

Fig. 9 on the same Plate exhibits two notable peculiarities—the irregularity of the cells and the copiously pitted deposit with which they are covered. The irregularity of the cells is mostly produced by the way in which the multiplication takes place, namely, by division of the original cell into two or more new ones, so that each of these takes the shape which it assumed when a component part of the parent cell. In this case the cells are necessarily very irregular, and when they are compressed from all sides they form solid figures of many sides, which, when cut through, present a flat surface marked with a variety of irregular outlines. This specimen is taken from the rind of a gourd.

The “pitted” structure which is so well shown in this figure is caused by a layer of matter which is deposited in the cell and thickens its walls, and

which is perforated with a number of very minute holes called "pits." This substance is called "secondary deposit." That these pits do not extend through the real cell-wall has already been shown in Fig. 12.

This secondary deposit assumes various forms. In some cases it is deposited in rings round the cell, and is clearly placed there for the purpose of strengthening the general structure. Such an example may be found in the mistletoe (Fig. 5), where the secondary deposit has formed itself into clear and bold rings that evidently give considerable strength to the delicate walls which they support. Fig. 10 shows another good instance of similar structure, differing from the preceding specimen in being much longer and containing a greater number of rings. This object is taken from an anther of the narcissus. Among the many plants from which similar objects may be obtained, the yew is perhaps one of the most prolific, as ringed wood-cells are abundant in its formation, and probably aid greatly in giving to the wood the strength and elasticity which have long made it so valuable in the manufacture of bows.

Before taking leave of the cells and their remarkable forms, we will just notice one example which has been drawn in Fig. 6. This is a collection of several cells, containing their nuclei, starting originally end to end, but swelling and dividing the top. This is a very young group of cells from the inner part of a lilac bud, and is here introduced for the purpose of showing the great similarity of all vegetable cells in their earliest stages of existence.

Having now examined the principal forms of cells, we arrive at the "vessels," a term which is applied to those long and delicate tubes which are formed of a number of cells set end to end, their walls of separation being absorbed.

In Fig. 19 the reader will find a curious example of the "pitted vessel," so called from the multitude of little markings which cover its walls, and are arranged in a spiral order. Like the pits and rings already mentioned, the dots are composed of secondary deposit in the interior of the tube, and vary greatly in number, function, and dimensions. This example is taken from the wood of the willow, and is remarkable for the extreme closeness with which the dots are packed together.

Immediately on the right hand of the preceding figure may be seen another example of a dotted vessel (Fig. 20), taken from a wheat stem. In this instance the cells are not nearly so long, but are wider than in the preceding example, and are marked in much the same way with a spiral series of dots. About the middle of the topmost cell is shown the short branch by which it communicates with the neighbouring vessel.

Fig. 23 exhibits a vessel taken from the common carrot, in which the secondary deposit is placed in such a manner as to resemble a net of irregular meshes wrapped tightly round the vessel. For this reason it is termed a "netted vessel." A very curious instance of these structures is given in Fig. 26, at the bottom of the Plate, where are represented two small vessels from the wood of the elm. One of them—that on the left hand—is

wholly marked with spiral deposit, the turns being complete ; while, in the other instance, the spiral is comparatively imperfect, and the cell-walls are marked with pits. If the reader would like to examine these structures more attentively, he will find plenty of them in many familiar garden vegetables, such as, for instance, the common radish, which contains many examples of these interesting finer parts.

There is another remarkable form in which this secondary deposit is sometimes arranged that is well worthy of our notice. An example of this structure is given in Fig. 18, taken from the stalk of the common fern. It is also found in very great perfection in the vine. On inspecting the illustration, the reader will observe that the deposit is arranged in successive bars or steps, like those of a winding staircase. In allusion to the ladder-like appearance of this formation, it is called "scalari-form" (Latin, *scala*, a ladder).

In the wood of the yew, to which allusion has already been made, there is a very peculiar structure, a series of pits found only in those trees that bear cones, and therefore termed the coniferous pitted structure. Fig. 16 is a section of a common cedar pencil, the wood, however, not being that of the true cedar, but of a species of fragrant juniper. This specimen shows the peculiar formation which has just been mentioned.

Any piece of deal or pine will exhibit the same peculiarities in a very marked manner, as is seen in Fig. 24. A specimen may be readily obtained by making a very thin shaving with a sharp plane.

In this example the deposit has taken a partially spiral form, and the numerous circular pits with which it is marked are only in single rows. In several other specimens of coniferous woods, such as the *Araucaria*, or Norfolk Island pine, there are two or three rows of pits.

A peculiarly elegant example of this spiral deposit may be seen in the wood of the common yew (Fig. 17). If an exceedingly thin section of this wood be made, the very remarkable appearance will be shown which is exhibited in the illustration. The deposit has not only assumed the perfectly spiral form, but there are two complete spirals, arranged at some little distance from each other, and producing a very pretty effect when seen through a good lens.

The pointed, elongated shape of the wood-cells is very well shown in the common elder-tree (see Fig. 15). In this instance the cells are without markings, but in general they are dotted like Fig. 21, an example cut from the woody part of the chrysanthemum stalk. This affords a very good instance of the wood-cell, as its length is considerable, and both ends are perfect in shape. On the right hand of the figure is a drawing of the wood-cell found in the lime-tree (Fig. 22), remarkable for the extremely delicate spiral markings with which it is adorned. In these wood-cells the secondary deposit is so plentiful that the original membranous character of the cell-walls is entirely lost, and they become elongated and nearly solid cases, having but a very small cavity in their centre. It is to this deposit that the hardness of wood is owing, and the reader will easily see the reason why the old wood is so

much harder than the young and new shoots. In order to permit the passage of the fluids which maintain the life of the part, it is needful that the cell-wall be left thin and permeable in certain places, and this object is attained either by the "pits" already described, or by the intervals between the spiral deposit.

At the right-hand bottom corner of Plate I (Fig. 28) may be seen a prettily marked object, which is of some interest. It is a slice stripped from the outer coat of the holly-berry, and is given for the purpose of illustrating the method by which plants are enabled to breathe the atmospheric air on which they depend as much as ourselves, though their respiration is slower. Among the mass of net-like cells may be seen three curious objects, bearing a rather close resemblance to split kidneys. These are the mouths, or "stomata," as they are scientifically called.

In the centre of the mouths may be seen a dark spot, which is the aperture through which the air communicates with the passages between the cells in the interior of the structure. In the flowering plants their shape is generally rounded, though they sometimes take a squared form, and they regularly occur at the meeting of several surface cells. The two kidney-shaped cells which form the "mouth" are the "guard-cells," so called from their function, since, by their change of form, they cause the mouth to open or shut, according to the needs of the plant. In young plants these guard-cells are very little below the surface of the leaf or skin, but in others they are sunk quite beneath the layer of cells forming

the outer coat of the tissue. There are other cases where they are slightly elevated above the surface.

Stomata are found chiefly in the green portions of plants, and are most plentiful on the under side of leaves. It is, however, worthy of notice, that when an aquatic leaf floats on the water, the mouths are only to be found on the upper surface. These curious and interesting objects are to be seen in many structures where we should hardly think of looking for them ; for instance, they may be found existing on the delicate skin which envelops the kernel of the common walnut. As might be expected, their dimensions vary with the character of the leaf on which they exist, being large upon the soft and pulpy leaves, and smaller upon those of a hard and leathery consistence. The reader will find ample amusement, and will gain great practical knowledge of the subject, by taking a plant, say a tuft of groundsel, and stripping off portions of the external skin or "epidermis" from the leaf or stem, etc., so as to note the different sizes and shapes of the stomata.

On the opposite bottom corner of Plate I, Fig. 25, is an example of a stoma taken from the outer skin of a gourd, and here given for the purpose of showing the curious manner in which the cells are arranged about the mouth, no less than seven cells being placed round the single mouth, and the others arranged in a partially circular form around them.

Turning to Plate II, we find several other examples of stomata, the first of which (Fig. 1) is obtained from the under surface of the buttercup leaf, by stripping off the external skin. The reader will

here notice the slightly waved outlines of the cell-walls, together with the abundant spots of chlorophyll with which the leaf is coloured. In this example the stomata appear open. Their closure or expansion depends chiefly on the state of the weather ; and, as a general rule, they are open by day and closed at night.

A remarkably pretty example of stomata and elongated cells is to be obtained from the leaf of the common iris, and may be prepared for the microscope by simply tearing off a strip of the epidermis from the under side of the leaf, laying it on a slide, putting a little water on it, and covering it with a piece of thin glass. (See Plate II, Fig. 2.) There are a number of longitudinal bands running along the leaf where these cells and stomata appear. The latter are not placed at regular intervals, for it often happens that the whole field of the microscope will be filled with cells without a single stoma, whilst elsewhere a group of three or four may be seen clustered closely together.

Fig. 3 on the same Plate exhibits a specimen of the beautifully waved cells, without mouths, which are found on the upper surface of the ivy leaf. These are difficult to arrange from the fresh leaf, but are easily shown by steeping the leaf in water for some time, and then tearing away the cuticle. The same process may be adopted with many leaves and cuticles, and in some cases the immersion must be continued for many days, and the process of decomposition aided by a very little nitric acid in the water, or by boiling.

On the same Plate are three examples of spiral

and ringed vessels, types of an endless variety of these beautiful and interesting structures. Fig. 4 is a specimen of a spiral vessel taken from the lily, and is a beautiful example of a double spire. The deposit which forms this spiral is very strong, and it is to the vast number of these vessels that the stalk owes its well-known elasticity. In many cases the spiral vessels are sufficiently strong to be visible to the naked eye, and to bear uncoiling. For example, if a leaf-stalk of geranium be broken across, and the two fragments gently drawn asunder, a great number of threads, drawn from the spiral vessels, will be seen connecting the broken ends. In this case the delicate membranous walls of the vessel are torn apart, and the stronger fibre which is coiled spirally within it unrolls itself in proportion to the force employed. In many cases these fibres are so strong that they will sustain the weight of an inch or so of the stalk.

In Fig. 5 is seen a still more bold and complex form of this curious structure ; being a coil of five threads, laid closely against each other, and forming, while remaining in their natural position, an almost continuous tube. This specimen is taken from the root of the water lily, and requires some little care to exhibit its structure properly.

Every student of natural history must, from time to time, observe the striking resemblance between one structure and another in an entirely different organism. For instance, these spiral structures which we have just examined are almost identical in appearance, and to some extent in their function, with the threads that are coiled within the breathing

tubes of insects. This is in both cases twofold, namely, to give support and elasticity to a delicate membrane, and to preserve the tube in its proper form, despite the bending to which it may be subjected. When we come to the anatomy of the insect in Chapter VII we shall see this structure further exemplified.

In some cases the deposit, instead of forming a spiral coil, is arranged in a series of rings, and the vessel is then termed "annulated." A very good example of this formation is given in Fig. 6, which is a sketch of such a vessel, taken from a stalk of the common rhubarb. To see these ringed vessels properly, the simplest plan is to boil the rhubarb until it is quite soft, then to break down the pulpy mass until it is flattened, to take some of the most promising portions with the forceps, lay them on the slide and press them down with a thin glass cover. They will not be found scattered at random through the fibres, which elsewhere present only a collection of several elongated cells, but are seen grouped together in bundles, and with a little trouble may be well isolated, and the pulpy mass worked away so as to show them in their full beauty. As may be seen in the illustration, the number of the rings and their arrangement is extremely variable. A better, but somewhat more troublesome, plan is to cut longitudinal sections of the stem, as described in our concluding chapter, when not only the various forms of cells and vessels, but their relations to each other, will be well shown. The numerous crystals of oxalate of lime, which make rhubarb so injurious a food for certain persons, will also be well seen.

These crystals are called "raphides," and are to be found in very many plants in different forms.

The hairs of plants form very interesting objects, and are instructive to the student, as they afford valuable indications of the mode in which plants grow. They are all appendages of and arise from the skin or epidermis ; and although their simplest form is that of a projecting and elongated cell, the variety of shapes which are assumed by these organs is inexhaustible. On Plate II are examples of some of the more striking forms, which will be briefly described.

The simple hair is well shown in Figs. 18, 19, and 32, the first being from the flower of the heart's-ease, the second from a dock-leaf, and the third from a cabbage. In Fig. 18 the hair is seen to be but a single projecting cell, consisting only of a wall and the contents. In Fig. 19 the hair has become more decided in shape, having assumed a somewhat dome-like form ; and in Fig. 32 it has become considerably elongated, and may at once be recognized as a true hair.

In Fig. 8 is a curious example of a hair taken from the rock-cress (*Arabis*), one of the cruciferous flowers, which is remarkable for the manner in which it divides into two branches, each spreading in opposite directions. Another example of a forked hair is seen in Fig. 13, but in this instance the hair is composed of a chain of cells, the three lower forming the stem of the hair, and the two upper being lengthened into the lateral branches. This hair is taken from the common southernwood.

In most cases of long hairs, the peculiar elongation is formed by a chain of cells, varying greatly in length and development. Several examples of these hairs will be seen on the same Plate.

Fig. 9 is a beaded hair from *Mirabilis* (Marvel of Peru), which is composed of a number of separate cells placed end to end, and connected by slender threads in a manner that strongly reminds the observer of a chain of beads strung loosely together, so as to show the thread by which they are connected with each other. Another good example is seen at Fig. 11, in a hair taken from the leaf of the sow-thistle. In this case the beads are strung closely together, and when placed under a rather high power of the microscope have a beautifully white and pearly aspect. The leaf must be dry and quite fresh, and the hairs seen against the green of the leaf. Fig. 39 represents another beaded hair taken from the Virginian spider-wort, or *Tradescantia*. This hair is found upon the stamens, and is remarkable for the beautifully beaded outline, the fine colouring, and the spiral markings with which each cell is adorned.

A still further modification of these many-celled hairs is found in several plants, where the hairs are formed by a row of ordinarily shaped cells, with the exception of the topmost cell, which is suddenly elongated into a whip-like form. Fig. 22 represents a hair of this kind, taken from the common groundsel; and Fig. 36 is a still more curious instance, found upon the leaf of the thistle. The reader may have noticed the peculiar white "fluffy" appearance of the thistle leaf when it is wet after a shower of rain.

This appearance is produced by the long lash-like ends of the hairs, which are bent down by the weight of the moisture, and lie almost at right angles with the thicker portions of the hair.

An interesting form of hair is seen in the "sting" of the common nettle. This may readily be examined by holding a leaf edgewise in the stage forceps, and laying it under the field of the microscope. In order to get the proper focus throughout the hair, the finger should be kept upon the fine adjustment, and the hair brought gradually into focus from its top to its base. The general structure of this hair is not unlike that which characterizes the fang of a venomous serpent. The acrid fluid which causes the pain is situated in the enlarged base of the hair, and is forced through the long straight tubular extremity by means of the pressure exerted when the sting enters the skin. At the very extremity of the perfect sting is a slight bulb-like swelling, which serves to confine the acrid juice, and which is broken off on the least pressure. The sting is seen in Fig. 43.

The extremities of many hairs present very curious forms, some being long and slender, as in the examples already mentioned, while others are tipped with knobs, bulbs, clubs, or rosettes in endless variety.

Fig. 12 is a hair of the tobacco leaf, exhibiting the two-celled gland at the tip, containing the peculiar principle of the plant, known by the name of "nicotine." The reader will see how easy it is to detect adulteration of tobacco by means of the microscope. The leaves most generally used for this purpose are the dock and the cabbage, so that if a

very little portion of leaf be examined the character of the hairs will at once inform the observer whether he is looking at the real article or its substitute.

Fig. 15 is a hair from the flower of the common yellow snapdragon, which is remarkable for the peculiar shape of the enlarged extremity, and for the spiral markings with which it is decorated. Fig. 16 is a curious little knobbed hair found upon the moneywort, and Fig. 17 is an example of a double-knobbed hair taken from the garden avens (*Geum*). Fig. 34 affords a very curious instance of a glandular hair, the stem being built up of cells disposed in a very peculiar fashion, and the extremity being developed into a beautiful rosette-shaped head. This hair came from the vervain (*Verbena*), a variety of which is to be found in most gardens.

Curiously branched hairs are not at all uncommon, and some very good and easily obtained examples are given on Plate II.

Fig. 28 is one of the multitude of branched hairs that surround the well-known fruit of the plane-tree, the branches being formed by some of the cells pointing outward. These hairs do not assume precisely the same shape; for Fig. 29 exhibits another hair from the same locality, on which the spikes are differently arranged, and Fig. 30 is a sketch of another such hair, where the branches have become so numerous and so well developed that they are quite as conspicuous as the parent stem.

One of the most curious and interesting forms of hair is that which is found upon the lavender leaf, and which gives it the peculiar bloom-like appearance on the surface.

This hair is represented in Figs. 40 and 41. On Fig. 40 the hair is shown as it appears when looking directly upon the leaf, and in Fig. 41 a section of the leaf is given, showing the mode in which the hairs grow into an upright stem, and then throw out horizontal branches in every direction. Between the two upright hairs, and sheltered under their branches, may be seen a glandular appendage not unlike that which is shown in Fig. 16. This is the reservoir containing the perfume, and it is evidently placed under the spreading branches for the benefit of their shelter. On looking upon the leaf by reflected light the hairs are beautifully shown, extending their arms on all sides ; and the globular perfume cells may be seen scattered plentifully about, gleaming like pearls through the hair-branches under which they repose. They will be found more numerous on the under side of the leaf.

This object will serve to answer a question which the reader has probably put to himself before now, namely, where are the fragrant resins, scents, and oils stored ? On Plate I, Fig. 16, will be seen the reply to the first question ; Fig. 41 of the present Plate has answered the second question, and Fig. 42 will answer the third. This figure represents a section of the rind of an orange, the flattened cells above constituting the delicate yellow skin, and the great spherical object in the centre being the reservoir in which the fragrant essential oil is stored. The covering is so delicate that it is easily broken, so that even by handling an orange some of the scent is sure to come off on the hands, and when the peel is stripped off and bent double, the reservoirs

burst in myriads, and fling their contents to a wonderful distance. This may be easily seen by squeezing a piece of orange peel opposite a lighted candle, and noting the distance over which the oil will pass before reaching the flame, and bursting into little flashes of light.

Returning to the barbed hairs, we may see in Fig. 35 a highly magnified view of the "pappus" hair of a dandelion, i.e. the hairs which fringe the arms of the parachute-like appendage which is attached to the seed. The whole apparatus will be seen more fully on Plate III, Figs. 44, 45, 46. This hair is composed of a double layer of elongated cells lying closely against each other, and having the ends of each cell jutting out from the original line. A simpler form of a double-celled, or more properly a "duplex" hair, will be seen on Plate II, Fig. 44. This is one of the hairs from the flower of the marigold and has none of the projecting ends to the cells.

In some instances the cell-walls of the hairs become greatly hardened by secondary deposit, and the hairs are then known as spines. Two examples of these are seen in Figs. 37 and 38, being picked from the Indian fig-cactus, and well known to those persons who have been foolish enough to handle the fig roughly before feeling it. The wounds which these spines will inflict are said to be very painful, and have been compared to those produced by the sting of the wasp.

Fig. 10 represents the extreme tip of a hair from the hollyhock leaf, subjected to a lens of very high power. Many hairs assume a star-like appearance,

an aspect which may be produced in different ways. Sometimes a number of simple hairs start from the same base, and by radiating in different directions produce the stellate effect. An example of this kind of hair may be seen in Fig. 14, which is a group of hairs from the hollyhock leaf. There is another mode of producing the star-shape which may be seen in Fig. 45, a hair taken from the leaf of the ivy.

Hairs are often covered with curious little branches or protuberances, and present many other peculiarities of form which throw a considerable light upon certain problems in scientific microscopy.

Fig. 33 represents a hair of two cells taken from the flower of the well-known dead-nettle, which is remarkable for the number of knobs scattered over its surface. A similar mode of marking is seen in Fig. 31, a club-shaped hair covered with external projections, found in the flower of the garden lobelia. In order to see these markings with advantage the  $\frac{1}{6}$  in. objective should be used. Fig. 21 shows this dotting in another hair from the dead-nettle, where the cell is drawn out to a great length, but is still covered with these markings.

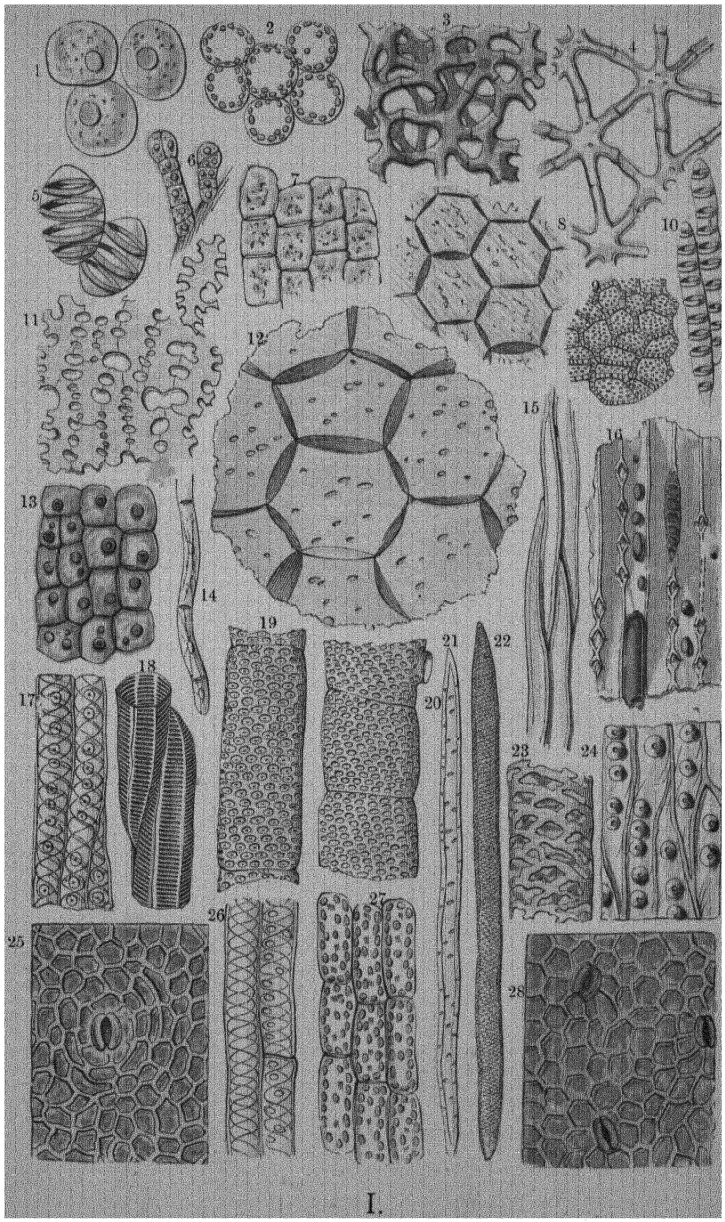
Fig. 20 is an example of a very curious hair taken from the throat of the pansy. This hair may readily be obtained by pulling out one of the petals, when the hairs will be seen at its base. Under the microscope it has a particularly beautiful appearance, looking just like a glass walking-stick covered with knobs, not unlike those huge, knobby, corkscrew-like sticks in which some farmers delight.

A hair of a similar character, but even more

# I

## FIG.

1. Strawberry, cellular tissue
2. Buttercup leaf, internal layer
3. Privet, seed coat, showing star-shaped cells
4. Rush, star-shaped cells
5. Mistletoe, cells with ringed fibre
6. Cells from interior of Lilac bud
7. Bur-reed, square cells from leaf
8. Six-sided cells, from stem of Lily
9. Angular dotted cells, rind of Gourd
10. Elongated ringed cells, anther of Narcissus
11. Irregular star-like tissue, pith of Bulrush
12. Six-sided cells, pith of Elder
13. Young cells from Wheat
14. Do. rootlets of Wheat
15. Wood-cells, Elder
16. Glandular markings and resin, " Cedar " pencil
17. Do. Yew
18. Scalariform tissue, stalk of Fern
19. Dotted duct, Willow
20. Do. stem of Wheat
21. Wood-cell, Chrysanthemum
22. Do. Lime-tree
23. Dotted duct, Carrot
24. Cone-bearing wood, Deal
25. Stoma, outer coat, Gourd
26. Ducts, Elm
27. Cellular tissue, stalk of Chickweed
28. Holly-berry, stomata, outer coat





curious, is found in the same part of the flower of the garden *Verbena* (see Fig. 27), and is not only beautifully translucent, but is coloured according to the tint of the flower from which it is taken. Its whole length is covered with large projections, the joints much resembling the antennæ of some insects; and each projection is profusely spotted with little dots, formed by elevation of the outer skin or cuticle. These are of some value in determining the structure of certain appearances upon petals and other portions of the flowers, and may be compared with Figs. 33 to 35 on Plate III.

Fig. 26 offers an example of the square cells which usually form the bark of trees. This is a transverse section of cork, and perfectly exhibits the form of bark cells. The reader is very strongly advised to cut a delicate section of the bark of various trees, a matter very easily accomplished with the aid of a sharp razor and a steady hand.

Fig. 24 is a transverse section through one of the scales of a pine-cone, and is here given for the purpose of showing the numerous resin-filled cells which it displays. This may be compared with Fig. 16 of Plate I. Fig. 25 is a part of one of the "vittæ," or oil reservoirs, from the fruit of the caraway, showing the cells containing the globules of caraway oil. This is rather a curious object, because the specimen from which it was taken was boiled in nitric acid, and yet retained some of the oil globules. Immediately above it may be seen (Fig. 23) a transverse section of the beech-nut, showing a cell with its layers of secondary deposit.

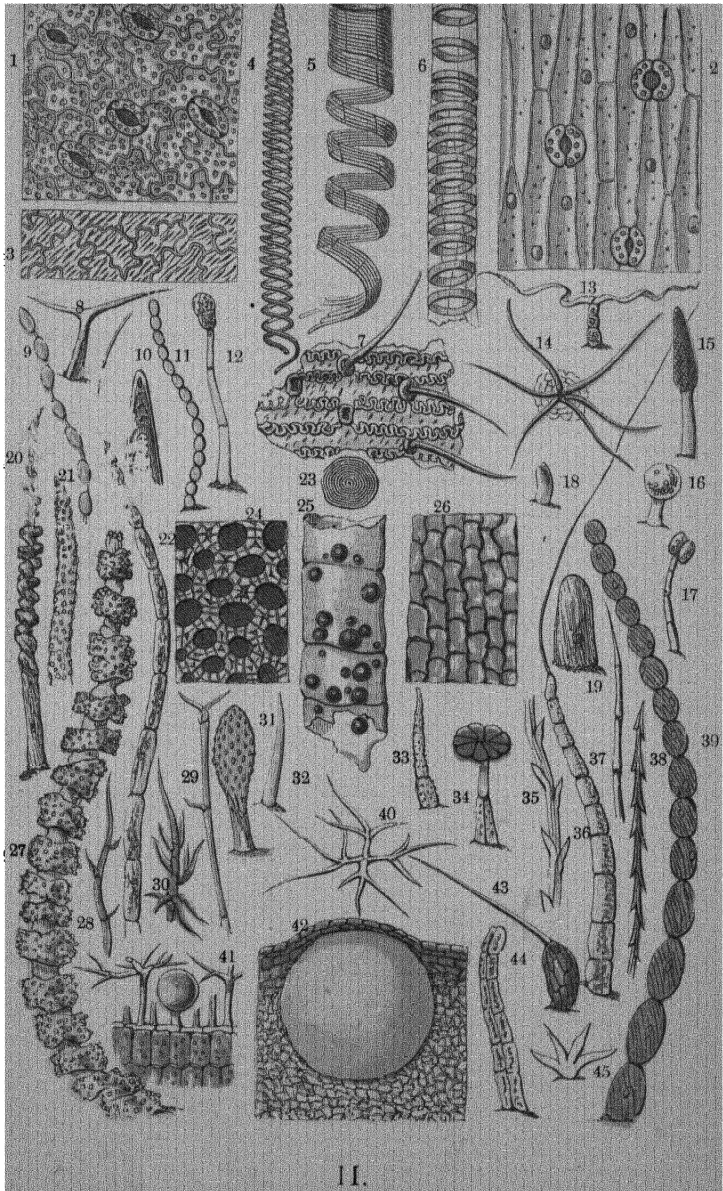
In the cuticle of the grasses and the mare's-tails

FIG.

1. Cuticle, Buttercup leaf
2. Do. Iris
3. Do. Ivy leaf
4. Spiral vessel, Lily
5. Do. root, (rhizome)  
Water Lily
6. Ringed vessel, Rhubarb
7. Chaff, after burning
8. Bifid hair, Arabis
9. Hair, Marvel of Peru
10. End of hair, leaf of Holly-  
hock
11. Hair, Sowthistle leaf
12. Do. Tobacco
13. Do. Southernwood
14. Group of hairs, Hollyhock  
leaf
15. Hair, Yellow Snapdragon
16. Do. Moneywort
17. Hair, Geum
18. Do. Flower of Heart's-  
ease
19. Do. Dock-leaf
20. Do. Throat of Pansy
21. Do. Dead-nettle flower
22. Do. Groundsel
23. Cell, Beech-nut

FIG.

24. Cell, Pine cone
25. Vittæ, Caraway Seed
26. Cork
27. Hair, flower of Garden  
Verbena
28. Do. fruit of Plane
29. Do. do.
30. Do. do.
31. Do. Lobelia
32. Do. Cabbage
33. Do. Dead-nettle flower
34. Do. Garden Verbena  
flower
35. Fruit-hair, Dandelion
36. Hair, Thistle leaf
37. Do. Cactus
38. Do. do.
39. Do. Virginian Spider-  
wort
40. Do. Lavender
41. Section, Lavender leaf,  
hairs and perfume-  
gland
42. Section, orange peel
43. Sting of Nettle
44. Hair, Marigold flower
45. Do. Ivy





is deposited a large amount of pure flint. So plentiful is this substance, and so equally is it distributed, that it can be separated by heat or acids from the vegetable parts of the plant, and will still preserve the form of the original cuticle, with its cell-walls, stomata, and hairs perfectly well defined.

Fig. 7, Plate II, represents a piece of wheat chaff, or "bran," that has been kept at a white heat for some time, and then mounted in Canada balsam. This specimen was prepared, so that the drawing could be made, by laying the chaff on a piece of platinum, and holding it over the spirit-lamp. A good example of the silex or flint in wheat is often given by the remains of a straw fire, where the stems may be seen still retaining their tubular form but fused together into a hard glassy mass. It is this substance that cuts the fingers of those who handle the wild grasses too roughly, the edges of the blades being serrated with flinty teeth, just like the swords of the ancient Mexicans, or the short crooked sword of the New Zealander.

## CHAPTER V

The Properties of Starch—Skin of Plants—Petals and their Surface Cells—Beautiful Markings of Pollen-grains—How a Plant is Fertilized—Various Types of Seeds.

STARCH is widely distributed throughout the vegetable kingdom and when examined by the microscope can be of fascinating interest. In most cases the starch-grains are manufactured by the so-called plastids from sugar, and deposit in the stems, roots, tubers, and seeds, a reserve store of food upon which the plant can draw as required. The grains are of variable size and shape, even in the same plant, but with sufficient general resemblance which permits of their being fairly easily identified after a moderate amount of practice. Sometimes the grains are found loosely packed in the interior of the cells, and are then easily recognized as starch grains by their peculiar form and the delicate lines with which they are marked ; but in many places they are pressed so closely together that they assume an hexagonal shape under the microscope, and bear a close resemblance to ordinary twelve-sided cells. In other plants, again, the grains never advance beyond the very minute form in which they seem to commence their existence ; and in some, such as the common oat, a great number of very little granules are compacted together so as to resemble one large grain.

There are several methods of detecting starch in those cases where its presence is doubtful ; and the two modes that are usually employed are polarized light and iodine. When polarized light is employed—a subject on which we shall have something to say presently—the starch grains assume the characteristic “black-cross,” and when a plate of selenite is placed immediately beneath the slide containing the starch grains, they glow with all the colours of the rainbow. The second plan is to treat them with a very weak solution of iodine and water, and in this case the iodine has the effect on the starch granules of staining them blue. They are so susceptible of this reaction that when the liquid is too strong the grains actually become black from the amount of iodine which they absorb.

Nothing is easier than to procure starch granules in the highest perfection. Take a raw potato, and with a razor cut a very thin slice from its interior, the direction of the cut not being of the slightest importance. Put this delicate slice upon a slide, drop a little water upon it, cover it with a piece of thin glass, give it a good squeeze, and place it under an objective of low power—the  $\frac{2}{3}$  in. will do—giving a magnification of about one hundred diameters. Any part of the slice, provided that it be very thin, will then present the appearance shown in Plate III, Fig. 9, where an ordinary cell of potato is seen filled loosely with starch grains of different sizes. Around the edges of the slice a vast number of starch granules will be seen, which have been squeezed out of their cells by pressure, and are now moving freely in the water. As cold

water has no perceptible effect upon starch, the grains are not altered in form by the moisture, and can be examined at leisure.

On focusing with great care, the surface of each granule will be seen to be covered with very minute dark lines, arranged in a manner which can be readily comprehended from Fig. 4, which represents two granules of potato starch as they appear when removed from the cell in which they took their origin. The dark spot at the end of the granule is called the "hilum," which is really a nucleus, and the lines around this represent the limits of successive layers of material as manufactured. The lines in question are very much better seen if the substage condenser be used with a small central stop, so as to obtain partial dark-field illumination. Otherwise they are often very difficult of detection.

In the earliest stages of their growth the starch granules appear to be destitute of these markings, or at all events they are so few and so delicate as not to be visible even with the most perfect instruments, and it is not until the granules assume a comparatively large size that the external markings become distinctly perceptible.

We will now glance at the examples of starch which are given in the Plate, and which are a very few out of the many that might be figured. Fig. 2 represents the starch of wheat, the upper grain being seen in front, the one immediately below it in profile, and the two others being examples of smaller grains. Fig. 6 is a specimen of a very minute form of starch, where the granules do not seem to advance beyond their earliest stage. This

specimen is obtained from the parsnip ; and although the magnifying power is very great, the dimensions of the granules are exceedingly small, and except by a very practised eye they would not be recognizable as starch grains.

Fig. 3 is a good example of a starch grain of wheat, exemplifying the change that takes place by the combined effects of heat and moisture. It has already been observed that cold water exercises little, if any, perceptible influence upon starch ; but it will be seen from the illustration that hot water has a very powerful effect. When subjected to the action of water at a temperature over 140° F., the granule swells rapidly, cracking at the edges of the rings, the contents escaping in a gelatinous mass, and the external membrane collapsing into the form which is shown in Fig. 3, which was taken out of a piece of hot pudding. A similar form of wheat starch may also be detected in bread, accompanied, unfortunately, by several other substances not generally presumed to be component parts of the "staff of life."

In Fig. 7 are represented some grains of starch from West Indian arrowroot, and Fig. 8 exhibits the largest kind of starch grain known, obtained from the tuber of *Canna edulis*, a plant similar in characteristics to the arrowroot. The popular name of this starch is "Tous les Mois," and under that title it may be obtained from dealers in objects for the microscope.

Fig. 10 shows the starch granules from Indian corn, as they appear before they are compressed into the honeycomb-like structure which has already been mentioned. Even in that state, however, if they

are treated with iodine, they exhibit the characteristics of starch in a very perfect manner. Fig. 11 is starch from sago, and Fig. 12 from tapioca, and in both these instances the several grains have been injured by the heat employed in preparing the respective substances for the market.

Fig. 13 exhibits the granules obtained from the root of the water-lily, and Fig. 14 is a good example of the manner in which the starch granules of rice are pressed together, though somewhat confusing to the beginner, the different shape being unlike any of those just described. It is worthy of note that the close adhesion of rice starch in this way is the cause of the peculiar grittiness which distinguishes rice flour to the touch. Fig. 15 is an example of the starch grains obtained from the underground stem of the horse-bean. The compound granule of the oat is shown by Fig. 16, together with some of the individual granules separated from the mass.

Whilst very easily acted on by heat, starch granules are very resistant to certain other reagents. Weak alkalies, in watery solution, readily attack them, but by treating portions of plants with caustic potash dissolved in strong spirit, the woody and other parts may be dissolved away; and after repeated washing with spirit the starch may be mounted. This, however, must never be in any glycerine medium, except by the method described in Chapter XII, where many hints are given for the successful preparation of objects for the microscope.

In Plate III, Fig. 1, may be seen a curious little drawing, which is a sketch of the laurel-leaf cut

transversely, and showing the entire thickness of the leaf. Along the top may be seen the delicate layer of "varnish" with which the surface of the leaf is covered, and which serves to give to the foliage its peculiar polish. This varnish is nothing more than the clear substance which binds all the cells together, and which is poured out very liberally upon the surface of the leaf. The lower part of this section exhibits the cells of which the leaf is built, and towards the left hand may be seen a cut end of one of the veins of the leaf, technically called a "fibro-vascular bundle."

We will now examine a few examples of surface cells.

Fig. 5 is a portion of the outer skin stripped from a chilli-pod (*Capsicum*), exhibiting the remains of the nuclei in the centre of each cell, together with the thickening of the walls of the cells and the numerous pores for the transmission of fluid. This is a very pretty specimen for the microscope, as it retains its bright red colour, and even in old and dried pods exhibits the characteristic markings.

In the centre of the Plate may be seen a wheel-like arrangement of the peculiar cells found on the petals of six different flowers, all easily obtainable, and mounted without difficulty.

Fig. 30 is the petal of a geranium (*Pelargonium*), a very common object on purchased slides. It is a most lovely subject for the microscope, whether it be examined with a low or a high power—in the former instance exhibiting a most beautiful "stippling" of pink, white, and black, and in the

latter showing the six-sided cells with their curious markings.

In the centre of each cell is seen a radiating arrangement of dark lines with a light spot in the middle, looking very like the mountains on a map. From observations it seems that the beautiful velvety aspect of flower petals is owing to these arrangements of the surface cells, and that their rich brilliancy of colour is due to the same cause. The centre of each cell-wall is elevated as if pushed up by a pointed instrument from the under side of the wall, and in different flowers this elevation assumes different forms. Sometimes it is merely a slight wart on the surface, sometimes it becomes a dome, while in other instance it is so developed as to resemble a hair.

The dark radiating lines are caused, state some authorities, by the wrinkling of the membrane forming the walls of the elevated centre, and not to be composed of "secondary deposit," as has generally been supposed.

Fig. 31 represents the petal of the common periwinkle, differing from that of the geranium by the straight sides of the cell-walls, which do not present the toothed appearance so conspicuous in the former flower. A number of little tooth-like projections may be seen on the interior of the cells, their bases affixed to the walls and their points tending toward the centre.

In Fig. 32 is shown the petal of the common garden balsam, where the cells are elegantly waved on their outlines, and have plain walls. The petal of the primrose is seen in Fig. 34, and that of the

yellow snapdragon in Fig. 33 ; in the latter instance the surface cells assume a most remarkable shape, running out into a variety of zigzag outlines that quite bewilders the eye when the object is first placed under the microscope. Fig. 35 is the petal of the common scarlet geranium.

In several instances these petals are too thick to be examined without some preparation, and glycerine will be found well adapted for that purpose. The young microscopist must, however, beware of forming his ideas from preparations of dried leaves, petals, or hairs, and should always procure them in their fresh state whenever he desires to make out their structure. Even a fading petal should not be used, and if the flowers are gathered for the occasion, their stalks should be placed in water, so as to give a series of leaves and petals as fresh as possible.

We now pass from the petal of the flower to the pollen, that coloured dust, generally yellow or white, which is found upon the stamens, and which is very plentiful in many flowers, such as the lily and the hollyhock.

This substance is found only upon the stamens or anthers of full-blown flowers (the anthers being the male organs), and is intended for the purpose of enabling the female portion of the flower to produce fertile seeds. In form the pollen grains are wonderfully diverse, affording an endless variety of beautiful shapes. In some cases the exterior is smooth and marked only with minute dots, but in many instances the outer wall of the pollen grain is covered with spikes, or decorated with stripes or

belts. A few examples of the commonest forms of pollen will be found on Plate III.

Fig. 17 is the pollen of the snowdrop, which, as will be seen, is covered with dots and marked with a definite slit along its length. The dots are simply tubercles in the outer coat of the grain, and are presumed to be formed for the purpose of strengthening the membrane, otherwise too delicate, upon the same principle which gives to "corrugated" iron such strength in proportion to the amount of material. Fig. 18 is the pollen of the wallflower, shown in two views, and having many of the same characteristics as that of the snowdrop. Fig. 19 is the pollen of the willow-herb, and is here given as an illustration of the manner in which the pollen aids in the germination of plants.

In order to understand its action, we must first examine its structure.

All pollen-grains are furnished with some means by which their contents when thoroughly ripened can be expelled. In some cases this end is accomplished by sundry little holes called pores; in others, certain tiny lids are pushed up by the contained matter; and in some, as in the present instance, the walls are thinned in certain places so as to yield to the internal pressure.

When a ripe pollen-grain falls upon the stigma (the moist part of the top of the pistil or female part—the lower portion is the ovary and the intermediate section the style) under suitable conditions it will commence to grow, not unlike a seedling potato, sending out a slender pollen-tube from one or other of the apertures already mentioned. In

Fig. 19 a pollen-tube is seen issuing from one of the projections and illustrates the manner of growth. The pollen-tube insinuates between the cells of the stigma and, continually developing, reaches down the style until making contact with the ovule. By very careful dissection of a fertile stigma, you may observe under a high power objective the beautiful sight of the pollen-tube winding along the tissues of the style.

The pollen-tube is nothing more than the interior coat of the grain, very much developed, and filled with a substance technically named "fovilla," composed of "protoplasm" (the semi-liquid substance which is found in the interior of cells), very minute starch grains, and some apparently oily globules.

In order to examine the structure of the pollen-grains properly, they should be examined under various circumstances—some dry, others placed in water to which a little sugar has been added, others in oil, and it can be very instructive to watch the effect of different chemical agents upon them.

Fig. 20 is the pollen of the common violet, and is easily recognizable by its peculiar shape and markings. Fig. 21 is the pollen of the musk-plant, and is notable for the curious mode in which its surface is belted with wide and deep bands, running spirally round the circumference. Fig. 22 exhibits the pollen of the apple, and Fig. 23 affords a very curious example of the raised markings upon the surface of the dandelion pollen. In Fig. 24 there are also some very wonderful markings, but they are disposed after a different fashion, forming a sort of network upon the surface, and leaving several large

free spaces between the meshes. The pollen of the lily is shown in Fig. 25, and is a good example of a pollen-grain covered with the minute dottings which have already been described.

Figs. 26 and 27 show two varieties of compound pollen, found in two species of heath. These compound pollen-grains are not of unfrequent occurrence, and are accounted for in the following manner.

The pollen is formed in certain cavities within the anthers, by means of the continual subdivision of the "parent-cells" from which it is developed. In many cases the form of the grain is clearly owing to the direction in which these cells have divided, but there is no great certainty on this subject. It will be seen, therefore, that if the process of subdivision be suddenly arrested, the grains will be found adhering to each other in groups of greater or smaller size, according to the character of the species and the amount of subdivision that has taken place.

Fig. 28 shows the pollen of the furze, in which are seen the longitudinal slits and the numerous dots on the surface; and Fig. 29 is the curiously shaped pollen of the tulip. The two large yellow globular figures at each side of the Plate represent the pollen of two common flowers; Fig. 36 being that of the crocus, and Fig. 37 a pollen-grain of the hollyhock. As may be seen from the illustration, the latter is of considerable size, and is covered with very numerous projections. These serve to raise the grain from a level surface, over which it rolls with a surprising ease of motion, so much so indeed

that if a little of this substance be placed on a slide and a piece of thin glass laid over it, the glass slips off as soon as it is in the least inclined, and forces the observer to fix it with paper or cement before he can place it on the inclined stage of the microscope. The little projections have a very curious effect under a high power, and require careful focusing to observe them properly ; for the diameter of the grain is so large that the focus must be altered to suit each individual projection.

The seeds of plants are even easier of examination than the pollen, and in most cases require nothing but a pocket lens and a needle for making out their general structure. The smaller seeds, however, must be placed under the microscope, many of them exhibiting very curious forms. The external coat of seeds is often of great interest, and needs to be dissected off before it can be rightly examined. The simplest plan in such a case is to boil the seed well, press it while still warm into a plate of wax, and then dissect with a pair of needles, forceps, and scissors under water. Many seeds may also be mounted in cells as dry objects, after being thoroughly dried themselves.

A few examples of the seeds of common plants are given at the bottom of Plate III.

Fig. 38 exhibits the fruit, popularly called the seed, of the common goosegrass (*Galium Aparine*), which is remarkable for the array of hooklets with which it is covered. Immediately above the figure may be seen a drawing of one of the hooks much magnified, showing its sharp curve (Fig. 39). It

is worthy of remark that the hook is not a simple curved hair, but a structure composed of a number of cells terminating in a hook.

Fig. 40 shows the seed, or rather the fruit, of the common red valerian, and is introduced for the purpose of showing its plumed extremity, which acts as a parachute, and causes it to be carried about by the wind until it meets with a proper resting-place. It is also notable for the series of strong longitudinal ribs which support its external structure. On Fig. 41 is shown a portion of one of the parachute hairs much more magnified.

The seed of the common dandelion, so dear to children in their play-hours, when they amuse themselves by puffing at the white plummy globes which tip the ripe dandelion flower-stalks, is a very interesting object even to their parents, on account of its beautiful structure, and the wonderful way in which it is adapted to the place which it fills. Fig. 45 represents the seed portion of one of these objects, together with a part of the parachute stem, the remainder of that appendage being shown lying across the broken stem.

The shape of the seed is not unlike that of the valerian, but it is easily distinguished from that object by the series of sharp spikes which fringe its upper end, and which serve to anchor the seed firmly as soon as it touches the ground. From this end of the seed proceeds a long slender shaft, crowned at its summit by a radiating plume of delicate hairs, each of which is plentifully jagged on its surface, as may be seen in Fig. 46, which shows a small portion of one of these hairs greatly

magnified. These jagged points are evidently intended to serve the same purpose as the spikes below, and to arrest the progress of the seed as soon as it has found a convenient spot.

Fig. 42 is the seed of the foxglove, and Fig. 43 the seed of the sunspurge, or milkwort. Fig. 47 shows the seed of the yellow snapdragon; remarkable for the membranous wing with which the seed is surrounded, and which is composed of cells with partially spiral markings. When viewed edgewise, it looks something like Saturn with his ring, or, to use a more homely but perhaps a more intelligible simile, like a marble set in the middle of a penny. Fig. 48 is a seed of mullein, covered with net-like markings on its external surface. These are probably to increase the strength of the external coat, and are generally found in the more minute seeds.

On Fig. 50 is shown a seed of the bur-reed; a structure which is remarkable for the extraordinary projection of the four outer ribs, and their powerful armature of turned-back barbs. Fig. 51 shows another form of parachute seed, found in the willow-herb, where the parachute is not expanded nearly so widely as that of the valerian; neither is it set upon a long slender stem like that of the dandelion, but proceeds at once from the top of the seed, widening towards the extremity, and having a very comet-like appearance. Two more seeds only remain, Fig. 49 being the seed of Robin Hood, one of the anemones or wind-flowers, and the other, Fig. 52, that of the musk mallow, being given in consequence of the thick coat of hairs with which it is covered.

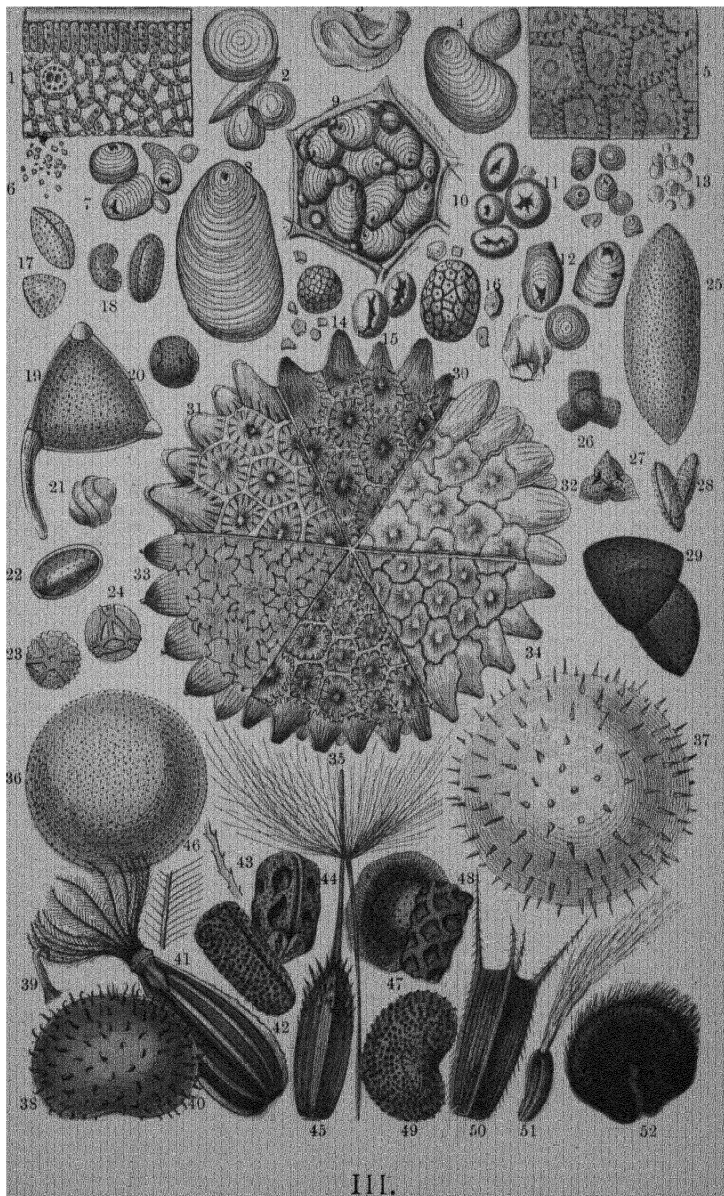
### III

FIG.

1. Laurel leaf, transverse section
2. Starch, Wheat
3. Do. from Pudding
4. Do. Potato
5. Outer Skin, Capsicum pod
6. Starch, Parsnip
7. Do. Arrowroot, West Indian
8. Do. " Tous les Mois "
9. Do. in cell of Potato
10. Do. Indian Corn
11. Do. Sago
12. Do. Tapioca
13. Root, Yellow Water-Lily
14. Starch, Rice
15. Do. Horsebean
16. Do. Oat
17. Pollen, Snowdrop
18. Do. Wallflower
19. Do. Willow Herb, a pollen-tube
20. Do. Violet
21. Do. Musk Plant
22. Do. Apple
23. Do. Dandelion
24. Do. Sowthistle
25. Do. Lily
26. Do. Heath

FIG.

27. Pollen, Heath, another species
28. Do. Furze
29. Do. Tulip
30. Petal, Pelargonium
31. Do. Periwinkle
32. Do. Golden Balsam
33. Do. Snapdragon
34. Do. Primrose
35. Do. Scarlet Geranium
36. Pollen, Crocus
37. Do. Hollyhock
38. Fruit, Galium, Goosegrass
39. A hook of ditto, more magnified
40. Seed, Red Valerian
41. Portion of Parachute of same, more magnified
42. Seed, Foxglove
43. Do. Sunspurge
44. Parachute, Dandelion seed
45. Seed, Dandelion
46. Do. Hair of Parachute
47. Do. Yellow Snapdragon
48. Do. Mullein
49. Do. Robin Hood
50. Do. Bur-reed
51. Do. Willow Herb
52. Do. Musk Mallow





## CHAPTER V

Flowerless Plants—Algæ and their Growth—Desmids—Diatoms  
—Volvox—Mildews and Moulds—Mosses and Ferns—  
Sea-weeds.

A LARGE number of suitable objects for examination can be selected from those curious examples of vegetable life known as the flowerless plants, comprising the mosses, ferns, and sea-weeds. Blight, mould, mildew, all such come within this group and are remarkable for their widespread distribution, being found in all parts of the globe and in any conditions of climate.

Not the least interesting are those minute forms which inhabit ponds and ditches ; some show such liveliness and apparent intelligence that they have for a long time been grouped with the animalcules, a species which cannot be seen without the aid of a magnifying glass. However, in spite of the name, the little organisms described elsewhere in this chapter, though of peculiar shape and habit, are indeed part of the great vegetable kingdom.

Fig. 1, Plate IV, represents one of the very lowest forms of vegetable life, known to the man of science as the *Palmella*, but to the general public as “gory dew.” It may be seen on almost any damp wall, extending in red patches of various sizes, looking just as if some blood had been dashed on the wall, and allowed to dry there. With a tolerably powerful

lens this substance can be resolved into the exceedingly minute cells depicted in the figure. Generally, these cells are single, but in many instances they are double, owing to the process of subdivision by which the plant grows, if such a term may be used.

Fig. 2 affords an example of another very low form of vegetable, the *Palmoglaea*, that green slimy substance which is so common on damp stones. When placed under the microscope, this plant is found to consist of a multitude of green cells, each being surrounded with a gelatinous substance. The mode of growth of this plant is very simple. A line appears across one of the cells, and after a while it assumes a kind of hour-glass aspect, as if a string had been tied tightly round its middle. By degrees the cell fairly divides into two parts, and then each part becomes surrounded with its own layer of gelatine, so as to form two separate cells, placed end to end.

In some circumstances the cells become detached, in others they cling together in masses. There appears to be, however, a limit to this form of growth which is really only possible under suitable conditions of low temperature and abundant moisture. When these are not available and are replaced by warmth and dryness, a process takes place known by the term conjugation, represented by the right hand objects of Fig. 2, which depicts the union and fusion of two cells. Each cell throws out a little projection; these meet together, and then uniting, form a sort of isthmus connecting the two main bodies. This rapidly widens, until the two cells become fused into one large body. The whole

subject of conjugation is very interesting, and is treated at great length in the standard books on biology. It will be sufficient here to say that the resulting cell will take up a state of rest or hibernation until moisture arrives which will permit of growth once more.

Few persons would suppose that the slug-like object, Fig. 3, the little rounded globules with a pair of hair-like appendages, and the round disc with a dark centre, are only different forms of the same organism. Such, however, is the case, and these are three of the modifications which the *Protococcus* undergoes. This vegetable may be seen floating like green froth on the surface of rain-water.

On collecting some of this froth and putting it under the microscope, it is seen to consist of a vast number of little green bodies, moving briskly about in all directions, and guiding their course with such apparent exercise of will-power that they might very readily be taken for animals. It may be noticed that the colour of the plant is sometimes red, and in that state it has been called the *Hæmatococcus*.

The resting state of this plant is shown in the round disc. After a while the interior substance splits into two portions ; these again subdivide, and the process is repeated until sixteen or thirty-two cells become developed out of the single parent-cell. These little ones then escape, and, being furnished with two long " cilia " or thread-like appendages, whirl themselves merrily through the water. When they have spent some time in this state, growing all the while, they lose their cilia, become clothed with a strong envelope, and pass into the resting stage

from which they had previously emerged. This curious process is repeated in endless succession, and causes a very rapid growth of the plant. The moving bodies are technically called zoospores, or living spores, and are found in many other plants besides those of the lowest order.

On Fig. 13 is delineated a very minute plant, called from its colour *Chlorococcus*. It may be found upon tree-trunks, walls, etc., in the form of green dust, and has been found to take part in forming the first stage of lichens.

A large and interesting family of the "confervoid algæ," as these low forms of vegetable life are termed, is the *Desmidiaceæ*, called in more common parlance desmids. The number of described species known is about two thousand, of which some seven hundred and fifty have been found in the British Isles. A few examples of this family are given in Plate IV.

They may be found in water, always preferring the cleanest and the brightest pools, mostly congregating in masses of green film at the bottom of the water, or investing the stems of plants. Their removal is not very easy, but is best accomplished by very carefully taking up this green slippery substance in a spoon, and straining the water away through fine muslin. They may also be separated by allowing a ring, covered with muslin, to float upon the surface of the water collected in a jar, for, being great lovers of light, they assemble where it is most abundant. An opaque jar should be used. For preservation, glycerine-gelatine seems to be the best fluid. A full description of these plants may be

found in *A Monograph of the British Desmidiaceæ*, by W. West and G. S. West.

Fig. 4 represents one of the species of *Closterium*, more than sixty species being described as British. These beautiful objects can be obtained from the bottom of almost every clear pool, and are of some interest on account of the circulating currents that may be seen within the living plants. A high power is required to see this phenomenon clearly. *Closteria* are reproduced in various ways. Mostly they divide across the centre, being joined for a while by two half-cells. Sometimes they reproduce by means of conjugation, the process being almost entirely conducted on the convex sides. Fig. 5 represents the end of a *Closterium*, much magnified in order to show the actively moving bodies contained within it.

Fig. 16 is a supposed desmid, called *Ankistrodesmus*, and presumed to be an earlier stage of *Closterium*.

Fig. 6 is a very pretty desmid called the *Pediastrum*, and valuable to the microscopist as exhibiting a curious mode of reproduction. The figure shows a perfect plant composed of a number of cells arranged systematically in a star-like shape ; Fig. 15 is the same species without the colouring matter, in order to show the shape of the cells. The *Pediastrum* reproduces by continual subdivision of the contents of each cell into a number of smaller cells, termed " gonidia " on account of their function on the perpetuation of the species. When a sufficient number has been formed, they burst through the envelope of the original cell, taking with them

a portion of its internal layer, so as to form a vesicle, in which they move actively. In a few minutes they arrange themselves in a circle, and after a while they gradually assume the perfect form, the whole process occupying about two days. Fig. 18 exhibits an example of the genus *Desmidium*. In this genus the cells are either square or triangular in their form, having two teeth at their angles, and twisted regularly throughout their length, causing the wavy or oblique lines which distinguish them. The plants of this genus are common, and may be found almost in any water. I may as well mention that I have obtained nearly all the preceding species, together with many others, from a little pond on Blackheath.

Fig. 7 is another desmid called *Scenedesmus*, in which the cells are arranged in rows of from two to ten in number, the cell at each extremity being often furnished with a pair of bristle-like appendages. Fig. 14 is another species of the same plant, and both may be found in any pond.

A common species of desmid is seen at Fig. 12, called *Sphærozosma*, looking much like a row of stomata set chainwise together. It multiplies by self-division.

Fig. 17 is a specimen of desmid named *Cosmarium*, plentifully found in ponds on heaths and commons, and having a very pretty appearance in the microscope, with its glittering green centre and beautifully transparent envelope. The manner in which the *Cosmarium* conjugates is very remarkable, and is shown at Fig. 19.

The two conjugating cells become very deeply

cleft, and by degrees separate, allowing the contents to pour out freely, and, as at present appears, without any envelope to protect them. The mass, however, soon acquires an envelope of its own, and by degrees assumes a dark reddish-brown tint. It is now termed a sporangium, and is covered with a vast number of projections, which in this genus are forked at their tip, but in others, which also form sporangia, are simply pointed. The *Closteria* conjugate after a somewhat similar manner, and it is not unfrequent to find a pair in this condition, but in their case the sporangium is quite smooth on its surface.

Another very remarkable family of confervoid algæ is that which is known under the name of *Oscillatoria*, from the oscillating movement of the plant. They are always long and filamentous in character, and may be seen moving up and down with a curious irregularity of motion. Their growth is extremely rapid, and may be watched under a tolerably powerful lens, thus giving many valuable hints as to the mode by which these plants are reproduced. One of the commonest species is represented at Fig. 8.

Figs. 9, 10, and 11 are examples of another family, called technically the *Zygnemaceæ*, because they are so constantly yoked together by conjugation. They all consist of a series of cylindrical cells, set end to end, and having their green contents arranged in similar patterns. Two of the most common and typical species are here given.

Fig. 9 is the *Spirogyra*, so called from the spiral arrangement of the chlorophyll; and Fig. 10 is the

*Tyndaridea*, or *Zygnema*, as it is called by some writers. A casual inspection will show how easy it is to distinguish the one from the other. Fig. 11 represents a portion of the *Tyndaridea* during the process of conjugation, showing the tube of connection between the cells and one of the spores.

We now arrive at the diatoms, so called because of their method of reproduction, in which it appears as if a cut were made right along the original cell. The commonest of these plants is the *Diatoma vulgare*, seen in Fig. 21 as it appears while growing. The reproduction of this plant is effected by splitting down the centre, each half increasing to the full size of the original cell; and in almost every specimen of water taken from a pond, examples of this diatom undergoing the process of division will be distinguished. It also grows by conjugation. The diatoms are remarkable for the delicate shell or flinty matter which forms the cell skeleton, and which will retain its shape even after intense heat and the action of nitric acid. While the diatoms are alive, swimming through the water, their beautiful markings are clearly distinct, glittering as if the form were spun from crystalline glass. Just above the figure, and to the right hand, are two outlines of single cells of this diatom, the one showing the front view and the other the profile.

Fig. 20 is an example of a diatom—*Cocconema lanceolatum*—furnished with a stalk. The left-hand branch sustains a “frustule” exhibiting the front view, while the other is seen sideways.

Another common diatom is shown in Fig. 23, and

is known by the name of *Synedra*. This constitutes a very large genus, containing about seventy known species. In this genus the frustules are at first arranged upon a sort of cushion, but in course of time they mostly break away from their attachment. In some species they radiate in every direction from the cushion, like the spikes of the ancient cavalier's mace.

Fig. 24 is another stalked diatom called *Gomphonema acuminatum*, found commonly in ponds and ditches. There are numerous species belonging to this genus. A pair of frustules are also shown which exhibit the beautiful flinty outline without the coloured contents (technically called endochrome).

Fig. 27 is a side view of a beautiful diatom, called *Eunotia diadema* from its diadem-like form. There are many species of this genus. When seen upon the upper surface, it looks at first sight like a mere row of cells with a band running along them ; but by careful arrangement of the light its true form may easily be made out.

Fig. 28 represents a very common fresh-water diatom, named *Melosira varians*. The plants of this genus look like a cylindrical rod composed of a variable number of segments, mostly cylindrical, but sometimes disc-shaped or rounded. An end view of one of the frustules is seen at the left hand, still coloured with its dots of endochrome, and showing the cylindrical shape. Immediately above is a figure of another frustule seen under both aspects with the endochrome removed.

A rather curious species of diatom, called *Cocconeis*

*pediculus*, is seen at Fig. 29 as it appears on the surface of common water-cress. Sometimes the frustules, which in all cases are single, are crowded very closely upon each other and almost wholly hide the substance on which they repose. Fig. 30 is another diatom of a flag-like shape, named *Achnanthes*, having a long slender filament attached to one end of the lower frustule, representing the flag-staff. There are many wonderful species of such diatoms, some running almost end to end like a bundle of sticks, and therefore called *Bacillaria*; others spreading out like a number of fans, such as the genus *Licmophora*; while some assume a beautiful wheel-like aspect, of which the genus *Meridion* affords an excellent example.

A very remarkable, and not uncommon, fresh-water diatom is the *Bacillaria paradoxa*. It looks, when at rest, like a broad brown ribbon of varying length. The diatoms lie across the ribbon, on edge, and slide upon each other exactly like the ladders of a fire-escape, so that the broad ribbon is converted into a fine long thread, which speedily closes up again into the original ribbon. The reason for this movement, and how it is effected, is absolutely unknown; indeed, nothing certain is known as to the way in which diatoms move, nor has ever a probable guess yet been made.

The last of the diatoms which we shall be able to mention in this work is that represented on Fig. 31. The members of this genus have the name of *Navicula*, on account of their boat-like shape and their habit of gliding through the water in a canoe-like fashion. There are many species of this genus,

all of which are notable for the graceful and varied courses formed by their outlines, and the extreme delicacy of their markings. In many species the markings are so extremely minute that they can only be made out with the highest powers of the microscope and the most careful illumination, so that they serve as test objects whereby the performance of a microscope can be judged by a practical man.

The large spherical figure in the centre of Plate IV represents an example of a family belonging to the confervoid algæ, and known by the name of *Volvox globator*.

This singular plant has been greatly bandied about between the vegetable and animal kingdoms, but seems now to be satisfactorily settled among the vegetables. In the summer it may be found in pools of water, sufficiently large to be visible to the naked eye, like a little green speck proceeding slowly through the water. When seen through the microscope, it appears as shown in the figure, and always contains within its body a number of smaller individuals, which after a while burst through the envelope of the parent and start upon an independent existence. On a closer examination, a further generation may be discovered even within the bodies of the children. The whole surface is profusely covered with little green bodies, each being furnished with a pair of movable cilia, by means of which the whole organism is moved through the water. These bodies are analogous to the zoospores already mentioned, and are connected with each other by a

network of filaments. Reproduction also takes place by conjugation as in other algæ. A more magnified representation of one of the green bodies is shown immediately above the larger figure. The volvox is apt to die soon when confined in a bottle.

Fig. 25 is the common yeast-plant, consisting simply of a chain of cells, which increase by budding, and only form spores when they have exhausted the nutriment in the fluid in which they live. Fig. 26 is a curious object, whose scientific name is *Sarcina ventriculi*. It is found in the human stomach, composed of spherical cells dividing in three directions, thus producing masses of cubes. Similar forms are often to be found in the air; for instance, a piece of coco-nut will exhibit this, and many other kinds of bacteria and moulds, after a few days' exposure to the air, preferably in a dark cupboard.

We now come to a fascinating group of minute fungi, the mildews and moulds, perhaps more commonly known as "blights." The study of these will make an absorbing hobby, for much information is still needed regarding many species. The life histories are in many cases somewhat complicated and therefore need unravelling. A good example is the mildew found on wheat. It has been discovered that the spores pass a stage of "resting" on the barberry (*Berberis vulgaris*), afterwards being transferred through the agency of moist breezes to the leaves and stem of the wheat plant. Fig. 32 shows the reddish brown spots. The name of this rust is *Puccinia graminis*, but because of the imperfect knowledge regarding its life-cycle, it was

formerly described under three different names, viz. *Ecidium*, *Puccinia*, and *Uredo*. Fig. 33 shows the spores in another stage of development. On Plate V, Fig. 7, is seen a variety of *Puccinia*, which grows on the common thistle. Fig. 1 and Fig. 10 illustrate allied types. Referring to Plate IV, Fig. 34, you will find the mould attacking decaying grapes. Fig. 35 is the blight of the potato, dreaded by all gardeners, found only too easily on the shrivelled leaves during the months of July and August. Now known as *Phytophthora infestans*, it has possessed other names until the history of its growth was understood. A fine exhibit for the microscope can be obtained if one of the diseased leaves is placed on damp blotting paper in a glass jar ; after a few hours a downy mildew will appear and a piece can then be detached and placed on a slide for examination.

The mosses and ferns afford an endless variety of interesting objects to the microscopist ; but as their numbers are so vast, and the details of their structure so elaborate, they can only be casually noticed in the present work. Fig. 38 represents a spore-case of the *Polypodium*, one of the ferns, as it appears while in the act of bursting and scattering the contents around. One of the spores is seen more magnified below. The spore-cases of many ferns may be seen bursting under the microscope, and have a very curious appearance, writhing and twisting like worms, and then suddenly filling the field with a cloud of spores. Fig. 9, Plate V, is a piece of the brown, chaff-like, scaly structure found at the base of the stalk of male fern cells,

showing the manner in which a flat membrane is formed. Fig. 39 is a capsule of the *Hypnum*, one of the mosses, showing the beautiful double fringe with which its edge is crowned. Fig. 2, Plate V, is the capsule of another moss, *Polytrichum*, to show the toothed rim ; on the right hand is one of the teeth much more magnified.

Fig. 3, Plate V, is the capsule of the *Jungermannia*, one of the liverworts, showing the " elaters " bursting out on every side, and scattering the spores. Fig. 4 is a single elater much magnified, showing it to be a spirally coiled filament, that, by sudden expansion, shoots out the spores. Fig. 5 is a part of the leaf of the *Sphagnum* moss, common in fresh water, showing the curious spiral arrangement of secondary fibre which is found in the cells, as well as the circular pores which are found in each cell at a certain stage of growth. Just below, and to the left hand, is a single cell greatly magnified, in order to show these peculiarities more strongly. Fig. 8 is part of a leaf of *Jungermannia*, showing the dotted cells.

Fig. 6, Plate V, is a part of a rootlet of moss, showing how it is formed of cells elongated and joined end to end.

On the common mare's-tail, or *Equisetum*, may be seen a very remarkable arrangement for scattering the spores. On the last joint of the stem is a process called a fruit-spike, being a pointed head around which are set a number of little bodies just like garden tables, with their tops outward. One of these bodies is seen in Fig. 40. From the top of the table depend a number of tiny pouches, which

are called sporangia ; these lie closely against each other, and contain the spores. At the proper moment these pouches burst from the inside, and fling out the spores, which then look like round balls with irregular surfaces, as shown in Fig. 40, *c*. This irregularity is caused by four elastic filaments, knobbed at the end, which are originally coiled tightly round the body of the spore, but by rapidly untwisting themselves cause the spore to leap about, and so aid in the distribution. A spore with uncoiled filaments is seen at Fig. 40, *b*. By breathing on them they may be made to repeat this process at will.

Fig. 36 is a common little sea-weed, called *Ectocarpus siliculosus*, that is found parasitically adhering to large plants, and is figured in order to show the manner in which the extremities of the branches are developed into sporangia. Fig. 37 is a piece of the common green laver, *Ulva latissima*, showing the green masses that are ultimately converted into zoospores, and by their extraordinary fertility cause the plant to grow with such rapid luxuriance wherever the conditions are favourable. Every possessor of a marine aquarium knows how rapidly the glass sides become covered with growing masses of this plant. The smaller figure above is a section of the same plant, showing that it is composed of a double plate of cellular tissue.

Fig. 41 is a piece of purple laver or "sloke," *Porphyra laciniata*, to show the manner in which the cells are arranged in groups of four, technically named "tetraspores." This plant has only one layer of cells.

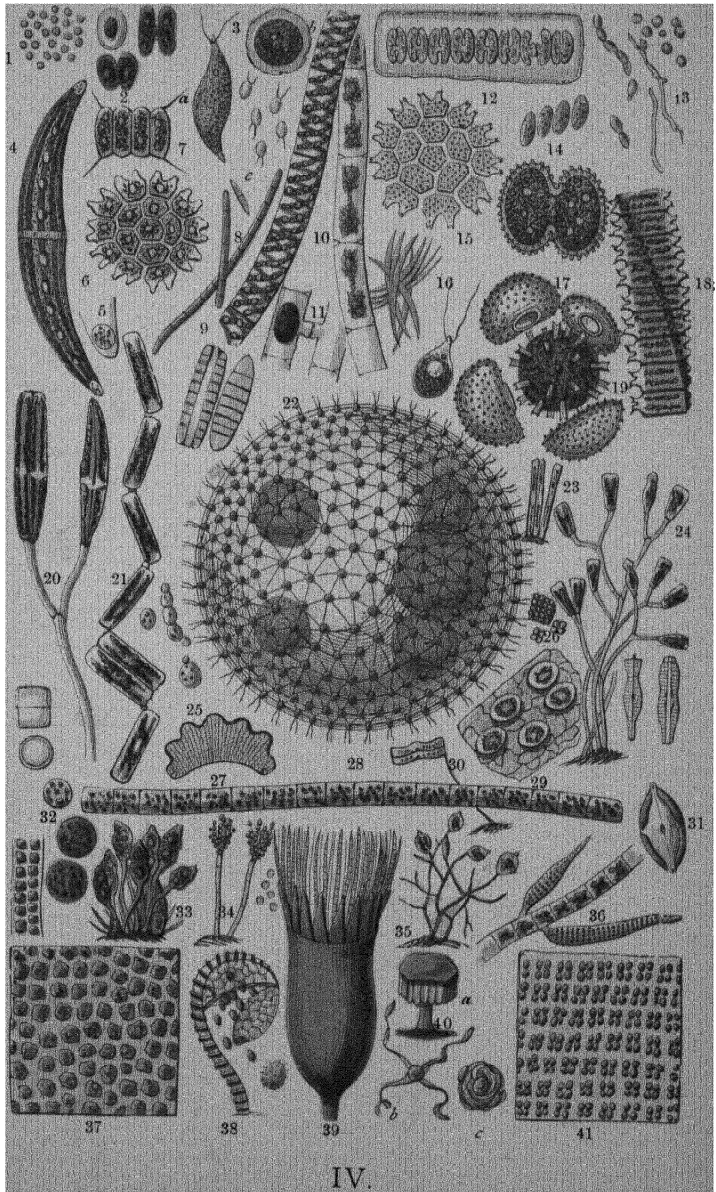
IV

FIG.

1. Gory Dew, *Palmella cruenta*
2. *Palmoglæa macrococca*
3. *Protococcus pluvialis*,  
a, in its motile, b, in its  
fixed state, c, zoospores
4. *Closterium*
5. Do. end more magnified
6. *Pediastrum*
7. *Scenedesmus*
8. *Oscillatoria*
9. *Spirogyra*
10. *Tyndaridea*
11. Do. spore
12. *Sphærozozma*
13. *Chlorococcus*
14. *Scenedesmus*
15. *Pediastrum*, to show cells
16. *Ankistrodesmus*
17. *Cosmarium*
18. *Desmidium*
19. *Cosmarium*, formation of  
Resting Spore
20. *Cocconema lanceolatum*
21. *Diatoma vulgare*  
Do. larger frustules, at  
the side
22. *Volvox globator*  
Do. single green body,  
above

FIG.

23. *Synedra*
24. *Gomphonema acuminatum*  
Do. larger frustules,  
below
25. Yeast
26. *Sarcina ventriculi*
27. *Eunotia diadema*
28. *Melosira varians*  
Do. two bleached frus-  
tules
29. *Cocconeis pediculus*
30. *Achnanthes exilis*
31. *Navicula amphibœna*
32. Uredo, "Red-rust" of  
Wheat
33. *Puccinia*, mildew of Corn
34. Do. mould on Grapes  
Do. sporules, beside it
35. Potato blight
36. *Ectocarpus siliculosus*
37. *Ulva latissima*
38. *Polypodium*  
Do. single spore, below
39. Moss capsule, *Hypnum*
40. Mare's-tail, *Equisetum*, a  
Do. do. b and c
41. *Porphyra laciniata*





On Plate V may be seen a number of curious details of the higher algæ.

Fig. 11 is the *Sphacelaria*, so called from the curious capsule cells found at the end of the branches, and termed sphacelæ. This portion of the plant is shown more magnified in Fig. 12. Another sea-weed is represented in Fig. 13, in order to show the manner in which the fruit is arranged ; and a portion of the same plant is given on a larger scale at Fig. 14.

A very pretty little sea-weed called *Ceramium* is shown at Fig. 15 ; and a portion showing the fruit much more magnified is drawn at Fig. 22. Fig. 23 is a little alga called *Myrionema*, growing parasitically on the preceding plant.

Fig. 16 is a section of a capsule belonging to the *Halydryis siliquosa*, showing the manner in which the fruit is arranged ; and Fig. 17 shows one of the spores more magnified.

Fig. 18 shows the *Polysiphonia parasitica*, a rather common species of a very extensive genus of sea-weeds, containing nearly three hundred species. Fig. 19 is a portion of the stem of the same plant, cut across in order to show the curious mode in which it is built up of a number of longitudinal cells, surrounding a central cell of large dimensions, so that a section of this plant has the aspect of a rosette when placed under the microscope. A capsule or "ceramidium" of the same plant is shown at Fig. 20, for the purpose of exhibiting the pear-shaped spores, and the mode of their escape from the parent-cell previous to their own development into fresh plants. The same plant has another

form of reproduction, shown in Fig. 21, where the tetraspores are seen imbedded in the substance of the branches. There is yet a third mode of reproduction by means of "antheridia," or elongated white tufts at the extremities of the branches. The cells produced by these tufts fertilize the rudimentary capsules, and so fulfil the function of the pollen in flowering plants.

Fig. 25 is the *Cladophora*, a green alga, figured to illustrate its mode of growth; and Fig. 26 represents one of the red sea-weeds, *Ptilota elegans*, beautifully feathered, and with a small portion shown also on a larger scale, in order to show its structure more fully. A good contrast to this species is seen on Fig. 27, and the mode in which the long, slender, filamentary fronds are built up of many-sided cells is seen just to the left hand of the upper frond. Fig. 24 is a portion of the lovely *Delesseria sanguinea*, given in order to show the formation of the cells, as also the arrangement by which the indistinct nervures are formed.

The figure on the bottom left-hand corner of Plate V is a portion of the pretty *Nitophyllum laceratum*, a plant belonging to the same family as the preceding one. The specimen here represented has a gathering of spores upon the frond.

Fig. 27 represents a portion of *Enteromorpha*, or common sea-grass, found on rocks about half-tide level. On the left hand of the figure, and near the top, is a small piece much magnified in order to show the form of its cells.

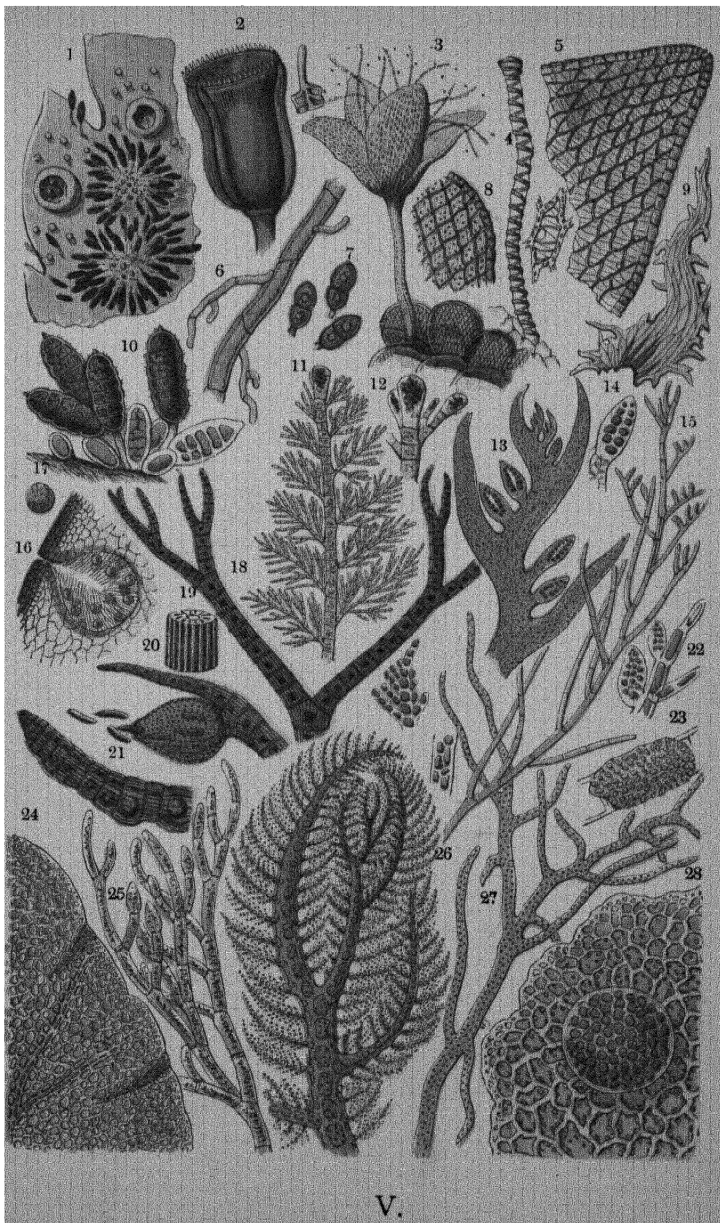
The sea-weeds form a group which offers scope for the investigation of many problems by the

young naturalist. It is very remarkable that little interest has been taken in this subject for many years in spite of the great work done by our English botanists of the Victorian period in sorting out and describing the numerous varieties. There is much to be done regarding the distribution of the species around our coasts.

## V

### FIG.

1. Rose leaf, with fungus
2. Moss capsule, *Polytrichum*
3. *Jungermannia*, capsule
4. Do. an elater more magnified
5. Leaf of Moss, *Sphagnum*
6. Rootlet, Moss
7. *Puccinia*, from Thistle
8. *Jungermannia*, leaf
9. Scale from stalk of male Fern
10. *Uredo*
11. *Sphacelaria filicina*
12. Do. top, more magnified
13. Sea-weed, showing fruit
14. Do. fruit, more magnified
15. *Ceramium*
16. Capsule, *Halidrys*
17. Spore of *Halidrys*
18. *Polysiphonia parasitica*
19. Do. stem, more magnified
20. Do. capsule, tetraspores escaping
21. Do. fruit, another form
22. *Ceramium*, fruit
23. *Myrionema*, parasitic Sea-weed
24. *Delesseria sanguinea*, frond
25. *Cladophora*
26. *Ptilota elegans*
27. *Enteromorpha clathrata*
28. *Nitophyllum laceratum*





## CHAPTER VII

Insects and their Structure—Antennæ—Eyes—Breathing Parts  
—Mouth Parts—Legs and Claws—Wings—Scales and Hairs  
—Eggs.

To gain a fair working knowledge of the great class of insects, the microscope is indispensable. By examining carefully the various parts here described, the beginner will become possessed of facts which will prove of value when later he is in a position to attempt more serious work.

The characteristic features of a typical insect are the head attached to which are the antennæ, the thorax bearing the wings (if any) and the three pairs of legs, and lastly, the abdomen which has no true appendages.

To distinguish the various joints of the legs, one of the larger beetles should be taken and then plainly seen will be the following parts, in the order named, commencing with that nearest the thorax ; the coxa, trochanter, femur, tibia, and the tarsus, which has at the extreme tip the claws. A little observation of insects in the garden and rock-pool will show how legs are adapted in different species for the varied work of running (beetles), jumping (grass-hoppers), swimming (water-boatman), and digging (mole-crickets).

Most insects have wings and usually possess two pairs. The flat, scale-covered wings of butterflies

and moths are too well known to need description. The flies such as, for instance, the ordinary house-fly, mosquito, hover-fly, etc., have one pair only; the other is represented by rudimentary knobbed organs commonly called balancers and quite easily seen when looked for. In the beetles the front pair are thickened to form a covering for the other pair which are folded up and tucked neatly underneath when not in use. The bees and wasps have two pairs of wings not unlike those of flies in general appearance. In flight they are held together by a row of hooks so that they appear to form together a single wing.

For examining insects under the microscope, stage forceps similar to that illustrated in Chapter II will be of some assistance. One of the stage spring clips can be disengaged and the corresponding part, shown in the lower portion of the figure, can be fitted in its place.

On Plate VI may be seen examples of the many beautiful objects which we can obtain with little difficulty. Most of these are of the antennæ, and the forms are as varied as the insects to which they belong.

The functions of the antennæ are not yet properly understood; much has been written about the subject which, to pursue further here, would take us into the study of psychology. We do know, however, that they are sensitive to waves of heat, light, sound, and odours. It can be noticed how particular insects are in keeping this part of their anatomy clean, and it is a pretty sight to watch an earwig gently pull one antenna at a time carefully through the mouth parts, removing any minute particles of dirt that may be there.

Fig. 15, Plate VI, represents a part of one of the joints belonging to the antennæ of the common house-fly; it is seen to be covered with a multitude of little depressions, some being small, and others very much larger. A section of the same antenna, but on a larger scale, is shown by Fig. 16, in order to exhibit the real form of these depressions. Nerves have been traced to these curious cavities, which evidently serve some very useful purpose, some authors thinking them to belong to the sense of smell, and others to that of hearing. A similar section taken from the antennæ of an ichneumon-fly is represented by Fig. 17.

We will now glance cursorily at the forms of antennæ which are depicted in the Plate.

Fig. 1 is the antenna of the common cricket, which consists of a vast number of little joints, each a trifle smaller than the preceding one, the whole forming a long, thread-like organ. Fig. 2 is taken from the grasshopper, and shows that the joints are larger in the middle than at either end.

Figs. 3 and 5 are from two minute species of cocktailed beetles (*Staphylinidæ*), which swarm through the summer months, and even in the winter may be found in profusion under stones and moss. The insect from which Fig. 5 was taken is so small that it is almost invisible to the naked eye, and was captured on the wing by waving a sheet of gummed paper under the shade of a tree. These are the tiresome little insects that so often get into the eye in the summer, and cause such pain and inconvenience until they are removed.

Fig. 4 shows the antenna of the tortoise beetle

(*Cassida*), so common on many leaves, and remarkable for its likeness to the reptile from which it derives its popular name. Fig. 6 is from one of the weevils, and shows the extremely long basal joint of the antennæ of these beetles, as well as the clubbed extremity. Fig. 7 is the beautifully notched antenna of the cardinal beetle (*Pyrochroa*), and Fig. 11 is the fan-like one of the common cockchafer. This specimen is taken from a male insect, and the reader will find his trouble repaid on mounting one similar as a permanent object. The club part of the antenna is composed of seven joints in the male and six in the female.

Fig. 12 is an antenna from one of the common ground beetles (*Carabus*) looking like a string of elongated pears, from the form of the joints. These beetles are very common in gardens, some of them being very large, about an inch in length, and rather handsome with their dull violet wing-cases.

Fig. 10 is the entire antenna of a fly (*Syrphus*), one of those pretty flies which may be seen hovering over one spot for a minute, and then darting off like lightning. The large joint is the one on which are found those curious depressions that have already been mentioned. Fig. 8 is one of the antennæ of a tortoise-shell butterfly (*Vanessa*), showing the slender, knobbed form which butterfly antennæ assume; and Figs. 13 and 14 are specimens of moths' antennæ, showing how they always terminate in a point. Fig. 13 is the beautiful feathery antenna of the ermine moth, and Fig. 14 is the toothed one of the tiger moth. In all these feathered and toothed antennæ of moths, the male

insects have them much more developed than the female, probably for the purpose of enabling them to detect the presence of their mates, a property which some possess in wonderful perfection. The male oak-egger moth, for example, can be obtained in any number by putting a female into a box with a perforated lid, placing the box in a room, and opening the window. In the course of the evening seven or eight males are seen to make their appearance, and they are so anxious to get at their intended mate that they will suffer themselves to be taken by hand.

Fig. 9 is an antenna of the male gnat, a most beautiful object, remarkable for the delicate transparency of the joints, and the exquisitely fine feathering with which they are adorned.

We will now examine the eyes of insects, many of which are excellent objects for our purpose.

In the centre of Plate IV may be seen the front view of the head of a bee, showing both kinds of eyes, three simple eyes arranged triangularly in the centre, and two large masses, compound eyes, at the sides.

The simple eyes, termed "ocelli," are from one to three in number, and usually arranged in a triangular form between the two compound eyes. Externally they look merely like shining rounded projections. The compound eyes consist of a number of elements, each part containing a lens and various cells shaped together in a rod-like form and terminating in a nerve. These elements are set close together so that, when examined externally, they resemble—end on—the shapes figured on

Plate VI. Their number varies and in some insects many thousands are needed to form a compound eye. It is even possible to take a multiple photograph of an image as seen through the eye of an insect, the water-beetle being a favourite object for this purpose.

Fig. 18 shows a portion of the compound eye of a butterfly, and Fig. 20 the same organ of the death's-head moth. A number of the protecting hairs may be seen still adhering to the eye of the butterfly. Fig. 22 is a remarkably good specimen of the eye of a fly showing the facets, nearly square, the tubes to which they are attached, and portions of the optic nerves. By way of comparison, Fig. 23 is part of the compound eye of a lobster, showing the facets quite square.

On Plate VIII, Figs. 6 and 12, the reader will find two more examples of eyes, these being taken from the spiders. Fig. 6 is an example of the eight eyes of the well-known zebra spider, so common on our garden walls and similar situations, hunting incessantly after flies and other prey, and capturing them by a sudden pounce. The eyes are like the ocelli of insects, and are simple in their construction. The number, arrangement, and situation of the eyes is extremely varied in spiders, and serves as one of the readiest modes of distinguishing the species. Fig. 12, Plate VIII, represents one of the curious eyes of the common harvest spider, perched on a prominence or "watch-tower" (as it has been aptly named), for the purpose of enabling the creature to take a better view of surrounding objects.

The breathing system of insects consists of air-

tubes known as tracheæ which ramify all parts of the body. Fig. 21, Plate VI, is part of this apparatus extracted and prepared from a silkworm. Parts of this terminate in external breathing-holes or spiracles as they are called; an example, much enlarged, may be seen on Plate VII, Fig. 34, taken from the wireworm (the larva of the skipjack beetle) to show the apparatus for excluding dust and admitting air. As these breathing-tubes extend throughout the whole body and limbs, they would fail to perform their office when the limbs were bent, unless for some especial provision. This is achieved by the winding of a very strong but slender filament between the membranes of which the tube is composed, so that it always remains open for the passage of air throughout all the bends to which it may be subjected. A little piece of this thread is seen, Fig. 21, unwound at the end of a small branch towards the top, and this thread is so strong that it retains its elasticity when pulled away from the tube, and springs back into its spiral form.

Fig. 28 represents the two tubercles found in many species of plant-lice, or aphids, so well known as garden pests. These tubercles are often referred to as honey-tubes because it was thought that the sweet fluid, popularly known by the name of honey-dew, was excreted by them when actually it is from the end of the alimentary canal. Ants are very fond of this substance and will take care of the aphids to ensure a constant supply.

The head of the same insect may be seen in Fig. 24, where the reader may observe the bright scarlet eye, and the long beak with which the aphid punctures

the leaves and sucks the sap. Fig. 29 is the head of the sheep-tick, exhibiting the organ by which it pierces the skin of the creature on which it lives. Fig. 25 is the head of another curious parasite, a mite, found upon the tortoise, and remarkable for the "rostrum" by means of which it retains its hold and at the same time sucks the blood from its host.

Turning to Plate VII, Fig. 4, we find the head of a ground beetle (*Carabus*), valuable as exhibiting the whole of the organs of the head and mouth.

Immediately above the compound eyes are seen the roots of the antennæ, those organs themselves being cut away. Above there are two pairs of similarly constructed organs termed the "maxillary palpi," because they belong to the lesser jaws or maxillæ, seen just within the pair of great curved jaws called the mandibles, which are extended in so threatening a manner. The "labial palpi," so called because they belong to the "labium," or under lip, are seen just within the others; the tongue is seen between the maxillæ, and the chin or "mentum" forms a defence for the base of the maxillæ and the palpi. A careful examination of a beetle's mouth with the aid of a pocket lens is very instructive as well as interesting, and the various parts can be dissected out with ease.

Fig. 1 on the same Plate shows the jaws of the hive bee, where the same organs are seen modified into many curious shapes. In the centre may be seen the tongue, elongated into a flexible and hair-covered instrument, used for sucking the honey from the interior of flowers. At each side of the

tongue are the labial palpi, having their outermost joints very small, and the others extremely large, the latter acting as a kind of sheath for the tongue. Outside the labial palpi are the maxillæ, separated in the specimen, but capable of being laid closely upon each other, and outside all are the mandibles.

The curiously elongated head of the scorpion-fly (*Panorpa*), seen at Fig. 7, affords another example of the remarkable manner in which these organs are developed in different insects. In this case the mandibles are small. Another elongated head, belonging to the daddy long-legs, is seen in Plate VI, Fig. 27, and well shows the compound eyes, the antennæ, and the palpi. Fig. 2 represents the coiled tongue of the butterfly; it is composed of the maxillæ, very greatly developed, and appearing as if each had originally been flat, and then rolled up so as to make about three-fourths of a tube. A number of spines are seen towards the tip, and one of these is shown on a larger scale at Fig. 3. This apparatus enables the butterfly to probe and separate material, such as soft fruits, before sucking up the liquid as food.

Fig. 11, in the centre of the Plate, shows one of the most curious examples of insect structure, the proboscis of the common bluebottle-fly. At each side, lower part, are seen the maxillary palpi covered with bristles or hairs as indeed most parts of this insect are. The darker centre portion is the chitinous skeleton which supports the fleshy tip or "labellæ." In the living state this tip is closed up like the two parts of a hinge, but in our figure it is shown flattened out as an object ready for examination with the

microscope. Each labella or lobe contains a number of tubes communicating the food canal with the outer surface. If a fly is observed feeding on a piece of sugar, this proboscis can be seen at work and often with a globule of liquid, at the tip, being a drop of saliva used to soften the foodstuff before sucking up through the tubes. All the tubes are strengthened by a number of incomplete rings, some of which are shown by Fig. 12, just above. The fine hairs upon the proboscis itself afford most admirable practice for the young microscopist. They should, when properly lighted and focused, be quite black and sharp. Any errors of manipulation will cause them to be "fuzzy."

Fig. 5 shows the tongue of the common cricket, a most elegantly formed organ, having a number of radiating bands covered with zigzag lines, due to the triangular plates of strengthening substance with which they are furnished, instead of the rings. A portion more highly magnified is shown at Fig. 6, exhibiting the manner in which the branches are arranged.

The legs of insects now claim our attention.

Fig. 9, Plate VII, shows the "pro-leg" of a caterpillar. The pro-legs are situated on the hinder parts of the caterpillar, and, being set in pairs, take a wonderfully firm hold of a branch or twig by pressure toward each other. They are fleshy and terminate in a fleshy pad. Around the pro-legs are arranged a series of sharp hooks, set with their points inwards, for greater power in holding. Fig. 10 represents one of the hooks more magnified.

Fig. 15 is the lower portion of the many-jointed legs of the long-legged spider (*Phalangium*). Fig. 17 is the leg of the glow-worm, showing the single claw with which it is armed. Fig. 26 shows the foot of the flea, furnished with two simple claws. Fig. 16 is the foot of the *Trombidium*, a genus of parasitic creatures, to which the well-known harvest-mite belongs. Fig. 26, Plate VI, shows the leg of an aphid, exhibiting the double claw, and the pad or cushion, which probably serves the same purpose as the pads found upon the feet of many other insects. Fig. 8 is the lower portion of the leg of the ant, showing the two claws and the curious pad in the centre, by means of which the insect is able to walk upon slippery surfaces. The daddy long-legs has a foot also furnished with a single pad (see Plate VI, Fig. 30). This part is seen under a very high power to be covered with long hair-like appendages, each having a little disc at the end, and probably secreting some glutinous fluid which will enable the creature to hold on to perpendicular and smooth surfaces.

Fig. 21 is the foot of one of the ichneumon-flies (*Ophion*), the hairy fringe being apparently for the purpose of enabling it to hold firmly to the caterpillar in which it is depositing its eggs. Ichneumon-flies belong to a parasitic group of the hymenoptera and beginners are often amazed to find that they have bred several of these insects from a caterpillar instead of the beautiful butterfly they had anticipated! Fig. 20 is a beautiful example of a padded foot, taken from the little red mite so plentifully found upon the dung-beetle (*Geotrupes*).

Fig. 18 is the foot of the common yellow dung-fly (plentiful in pasture lands), having two claws and two pads; and Fig. 19 shows the three pads and two claws found in the foot of one of the robber-flies.

Few microscopic objects call forth such general and deserved admiration as the fore-foot of the male water-beetle (*Dytiscus*), when properly prepared and mounted, for which see Fig. 13.

On examining this preparation under the microscope, it is seen that three of the joints are greatly expanded, and that the whole of their under surface is covered profusely with certain wonderful projections, which are known to act as suckers. One of them is exceedingly large, and occupies considerable space, its hairs radiating like the rays of the heraldic sun. Another is also large, but scarcely half the diameter of the former, and the remainder are small, and mounted on the extremities of delicate footstalks, looking something like wide-mouthed trumpets. In the specimen from which the drawing was taken the smaller suckers are well shown, as they protrude from the margin of the foot. One of the larger suckers is seen more magnified on Fig. 14.

Plate VIII, Fig. 1, illustrates the manner in which the muscles of insects do their work, being attached in the limbs to the central tendon, thus giving very great strength. This leg is taken from the water-boatman (*Notonecta*), and has been mounted in Canada balsam.

On Plate VII, Fig. 29, may be seen a curiously formed creature. This is the larva of the tortoise beetle (*Cassida*), the skin having been flattened and mounted in Canada balsam. The spiracles are

visible along the sides, and at the end is seen a dark fork-like structure. This is one of the peculiarities of this creature, and is employed for the purpose of carrying the refuse of its food, which is always piled upon its back, and retained in its place by the forked spines, aided probably by the numerous smaller spines that project from the side.

Fig. 33 shows part of the stomach and gastric teeth of the grasshopper. This structure may be seen to perfection in the "gizzard," as it is called, of the great green grasshopper (*Tettigonia viridissima*). The organ looks like a sudden swelling of the œsophagus, and when slit longitudinally under water, the teeth may be seen in rows set side by side, and evidently having a great grinding power. The common house cricket has a similar organ of remarkable beauty. Just above (Fig. 27) is the corresponding structure in the hive bee, three of the teeth being shown separately at Fig. 28.

We now cast a rapid glance at the wings of insects.

They have no analogy, except in their use, with the wings of birds, as they are not modifications of existing limbs, but entirely separate organs. They consist of two membranes united at their edges, and traversed and supported by sundry branches or "nervures," serving as useful guides to entomologists for separating the insects into their genera. Indeed, the general character of the wings has long been employed as the means of dividing the insect class into their different orders, as may be seen in any work on entomology. The typical number of wings

is four, but it often happens that two are almost wholly absent, or that the uppermost pair are thickened into a shell-like kind of substance which renders them useless for flight; while in many insects, such as the ground beetles and others, the upper wings become hardened into firm coverings for the body.

Fig. 22 shows two of the wings of a humble bee, together with their nervures, and the peculiar system by which the upper and lower pair are united together at the will of the insect. At the upper edge of the lower wing, and nearly at its extremity, may be seen a row of very tiny hooks, shown on a larger scale at Fig. 25. These hooklets hitch into the strengthened membrane of the upper wing, which is seen immediately above them, and so conjoin the two together. The curious wing-hooks of the aphid may be seen on Fig. 24, very highly magnified.

Fig. 31 is the wing of the moth-like fly (*Psychoda*), that odd little insect which is seen hopping and popping about on the windows of outhouses and similar localities, and is so hard to catch. The whole wing is plentifully covered with elongated scales, and is a most lovely object under any power of the microscope. These scales run along the nervures and edges of the wings, and part of a nervure is shown more highly magnified at Fig. 32.

At Fig. 23 is shown the wing of one of the hemipterous insects, common along the banks of ditches and in shady lanes, and known by the name of *Cixius*. It is remarkable for the numerous spots which stud the nervures, one being always found at

each forking, and the others being very irregularly disposed.

Fig. 30 is one of the balancers or "halteres" of the house-fly. These organs are found in the two-winged insects, and are evidently modifications of the second pair of wings. They are covered with little vesicles, and protected at their base by scales. Some writers suppose that the sense of smell resides in these organs. Whatever other purpose they may serve, they clearly aid in the flight, as, if the insect be deprived of one or both of the balancers, it has the greatest difficulty in steering itself through the air.

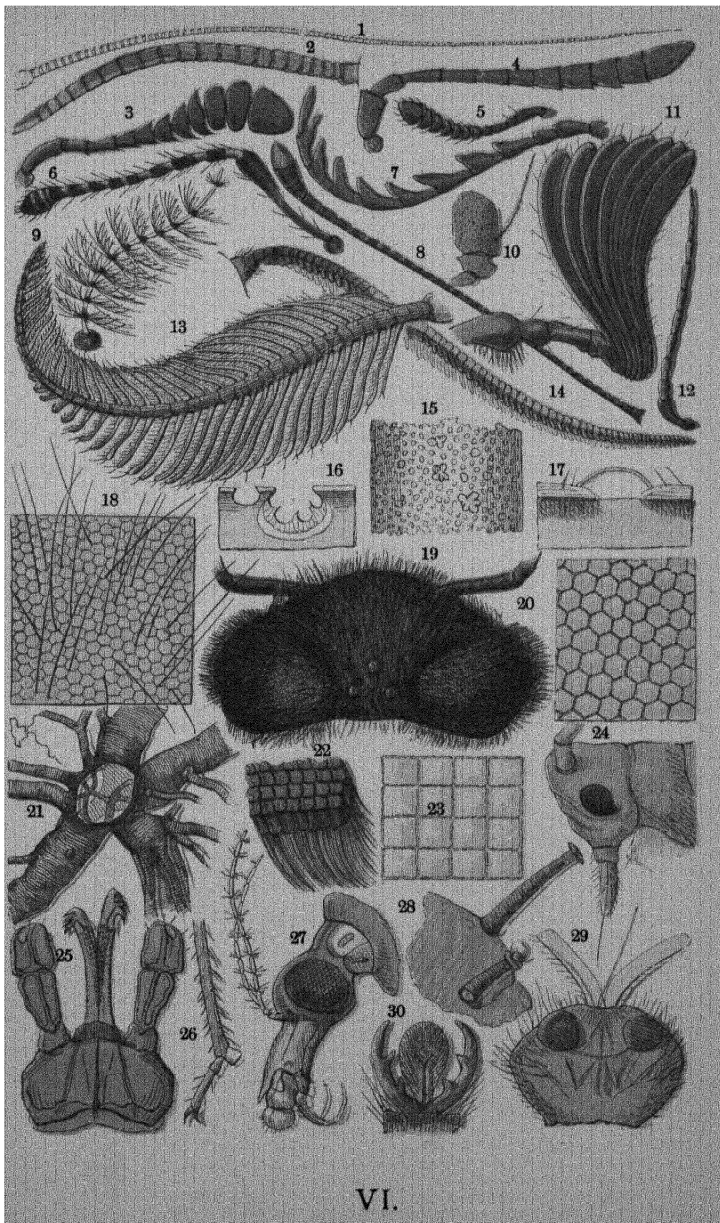
The wings of insects are mostly covered with hairs or scales, several examples of which are given in Plate VIII. Fig. 4 shows one of the scales of the fritillary butterfly, exhibiting the double membrane—part of which has been torn away—and the beautiful lines of dots with which it is marked. The structure of the scales is further shown by a torn specimen of tiger moth scale seen on Fig. 16. On many scales these dots assume a "watered" aspect when the focus or illumination changes, an example of which may be seen in Fig. 15, a scale of the peacock butterfly.

Fig. 11 is one of the ordinary scales of the azure blue butterfly, and Fig. 10 shows one of the curious "battledore" scales of the same insect, with its rows of distinct dottings. Fig. 14 is one of the prettily tufted scales of the orange-tip butterfly, and Fig. 8 is the splendid branched scale of the death's-head moth. Fig. 19 shows a scale of the silver-fish (*Lepisma saccharina*), a little silvery

## VI

FIG.

1. Antenna, Cricket
2. Do. Grasshopper
3. Do. Staphylinus
4. Do. Cassida
5. Do. Staphylinus
6. Do. Weevil
7. Do. Pyrochroa
8. Do. Butterfly, Tortoiseshell
9. Do. Gnat, male
10. Do. Syrphus
11. Do. Cockchafer, male
12. Do. Ground Beetle
13. Do. Ermine Moth
14. Do. Tiger Moth
15. Do. House-fly
16. Do. do. section
17. Do. Ichneumon
18. Eye of Butterfly
19. Eyes, Bee
20. Eye, Death's-Head Moth
21. Breathing-tube, Silkworm
22. Eye, Fly
23. Do. Lobster
24. Do. Aphid
25. Mouth-parts, Parasite of Tortoise
26. Hind leg, Aphid
27. Head, Daddy-long-legs
28. Tubercles of Aphid
29. Head, Sheep-tick
30. Foot, Daddy-long-legs





creature with glistening skin, and long bristles at the head and tail, that is found running about cupboards, window-sills, and similar places. It is difficult to catch with the fingers, as it slips through them easily; but by holding a cover-glass in a pair of forceps, and pressing it upon one of the little creatures, a number of the scales may be caused to adhere to it, and these should be mounted dry for examination. The gnats also possess very pretty scales, with the ribs projecting beyond the membrane.

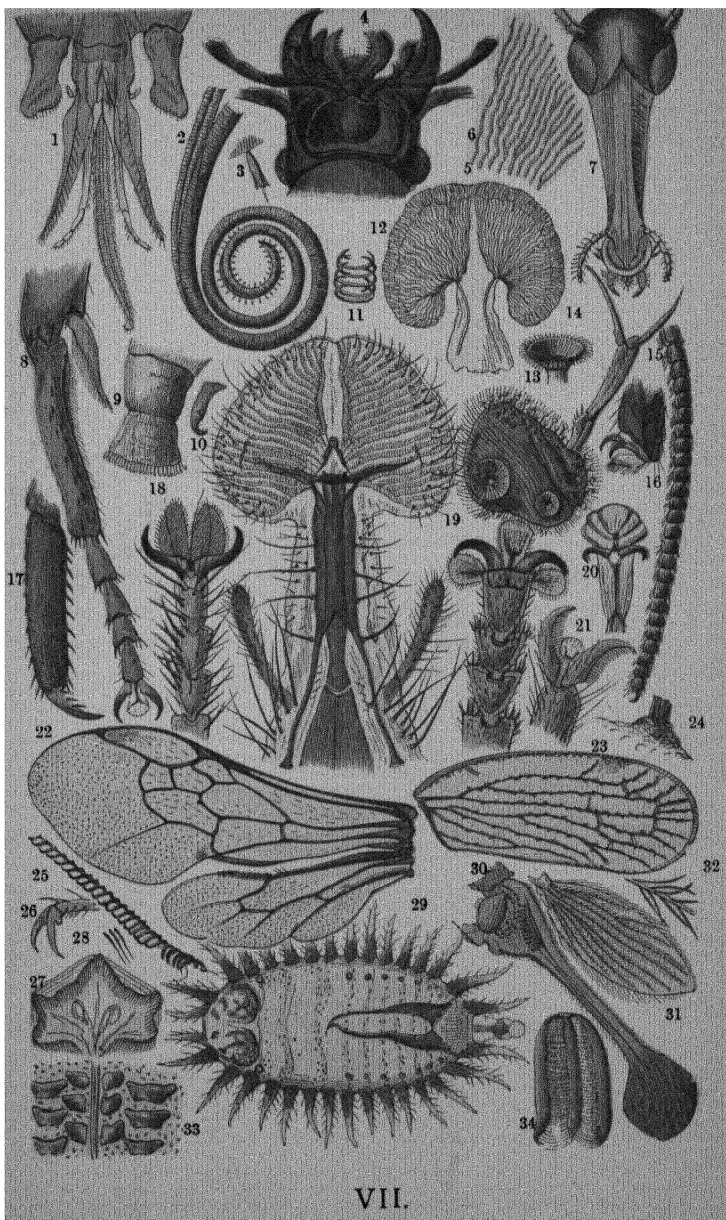
Fig. 21 is a scale from the common spring-tail (*Podura plumbea*), a little creature which is found plentifully in cellars and other damp places, skipping about with great activity. Some flour scattered on a piece of paper is a sure trap for these. Fig. 3 is one of the scales taken from the back of the celebrated diamond-beetle, showing the cause of the magnificent gem-like aspect of that insect. We have in England many beetles which, although much smaller, are quite as splendid when exhibited under a microscope by reflected light. The wing-case or "elytron" of a little green weevil, very common in the hedges, may be seen on Plate XII, Fig. 10.

The reader will observe that all these scales are furnished with little root-like appendages, by means of which they are affixed to the insect. Fig. 13 shows a portion of the wing of the azure blue butterfly, from which nearly all the scales have been removed, for the purpose of exhibiting the pits or depressions in which they had formerly been fastened, and one or two of the scales are left still adherent to their places. The scales are arranged

## VII

FIG.

1. Tongue, Hive Bee
2. Do. Butterfly
3. Do. do. one of the barrel-shaped bodies
4. Head, Ground Beetle
5. Tongue, Cricket
6. Do. do.
7. Head, Scorpion Fly (*Panorpa*)
8. Leg, Ant
9. Pro-leg, Caterpillar
10. Do. do. single hook
11. Proboscis, Fly
12. Do. do. " modified trachea "
13. Part of Foreleg of Water Beetle (*Dytiscus*)
14. Do. large sucker
15. Leg, long-legged Spider (*Phalangium*)
16. Do. Harvest-mite (*Trombidium*)
17. Do. Glow-worm
18. Do. Dung-fly
19. Do. Robber fly
20. Do. Red mite
21. Claws and Pad, Ophion
22. Wings, Humble Bee
23. Do. Cixius
24. Wing hooks, hind wing of Aphid
25. Wing hooks, Humble Bee
26. Foot, Flea
27. Gizzard, Bee
28. Three teeth of do.
29. Cast skin, Larva of Tortoise Beetle
30. Balancer, Blow-fly
31. Wing, moth-like fly (*Psychoda*)
32. Do. do. part of a nervure with scales
33. Gizzard, Grasshopper
34. Spiracle, Wireworm





in equal rows like the slates of a housetop, as may be seen on Fig. 18, which represents part of the same wing, to show the scales overlapping each other, and the elegant form which they take near the edges of the wing, so as to form a delicate fringe. The long hair-like down which covers the legs and bodies of the moths and butterflies (which are called lepidoptera, or scale-winged insects, in consequence of this peculiarity), is seen under the microscope to be composed of scales very much elongated, as is shown in Fig. 17, a portion taken from the leg of a tiger moth.

The eggs of insects are all very beautiful, and three of the most curious forms are given on Plate VIII.

Fig. 2 is the empty egg of the gad-fly, as it appears when fastened to a hair of the horse. Fig. 5 represents the pretty ribbed egg of the common tortoise-shell butterfly; and Fig. 7 is the very beautiful egg of the bed-bug, worthy of notice on account of the curious lid with which its extremity is closed, by means of which the young larva creeps out as soon as it is hatched.

The feathers of birds, and the fur of animals, will furnish many examples of the eggs of parasites, some of which are of extreme beauty. The feather or hair may be mounted in a cell without disturbing the eggs, which should, however, be heated sufficiently to kill the embryo if present.

Fig. 9 shows the penetrating portions of the sting of the wasp. The two barbed stings are seen lying one at each side of their sheath, and a single barb

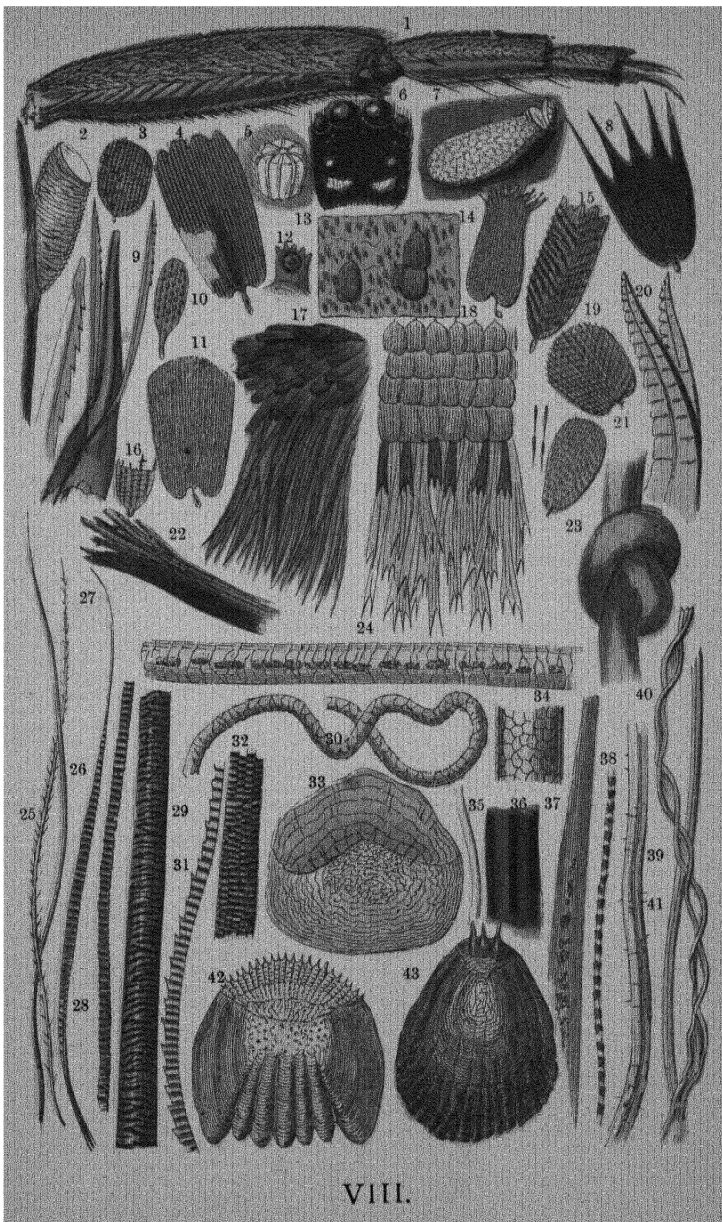
## VIII

**FIG:**

1. Leg, Water-boatman
2. Gadfly, empty egg
3. Scale, Diamond Beetle
4. Scale, Fritillary
5. Egg, Tortoiseshell Butterfly
6. Head and Eyes, Zebra Spider
7. Eggs, Bed-Bug
8. Scale, Death's-Head Moth
9. Sting, Wasp
10. Scale—battledore, Azure Blue
11. Do. ordinary scale
12. Eye, Harvest Spider
13. Wing Membrane, Azure Blue
14. Scale, Orange-tip butterfly
15. Do. Peacock Butterfly
16. Do. Tiger Moth
17. Do. Thigh of Tiger Moth
18. Wing and Scales, Azure Blue
19. Scale, Lepisma
20. Ovipositor, Sawfly

**FIG:**

21. Scale, Podura
22. Hair, Human
23. Do. Human Beard
24. Do. do. aged
25. Do. Humble Bee
26. Do. Tiger Moth, caterpillar
27. Do. Dormouse
28. Do. Rat
29. Do. do. long hair
30. Do. Sheep
31. Do. Mole
32. Do. Rabbit
33. Scale, Greenbone Pike
34. Hair, Red Deer
35. Do. fine, Sea Mouse
36. Do. do. large
37. Do. do. Badger
38. Do. do. long-eared Bat
39. Fibre, Linen
40. Do. Cotton
41. Do. Silk
42. Scale, Perch
43. Do. do.





is drawn a little to the left on a very much larger scale. It is by reason of these barbs that the sting is always left adhering to the wound, and is generally drawn wholly out of the insect.

The sting is only found in female insects, and is supposed to be analogous to the "ovipositor" of other insects, i.e. the instrument by which the eggs are deposited in their places. Fig. 20 shows the curious egg-placing apparatus of one of the saw-flies. The backs of these "saws" work in grooves, and they work alternately, so that the fly takes but a very short time in cutting a slit in the young bark of a tender shoot, and laying her eggs in the slit. When she has completed one of these channels, she sets to work upon another, and in the early spring the young branches of the gooseberry bushes may be seen plentifully covered with these grooves and the eggs. When hatched, black caterpillar-like grubs come out from the eggs and devastate the bushes.

## CHAPTER VIII

Pond-life—How to Collect Suitable Objects—The Freshwater Sponge — Amœba—Infusoria—Bursaria—Stentor—Vorticella.

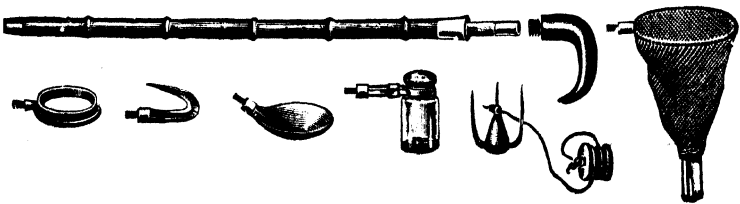
POND hunting is one of the most popular of the many diversions attached to the study of microscopic life. Here we have a hobby which can be followed at all times of the year, and one that is particularly interesting because the life-history of the little creatures can be examined with ease and comfort.

A few words on the selection of the outfit for collecting are necessary. It is really essential to have some form of "collecting stick" for work among the ponds and ditches. The reason should be fairly obvious because some means must be on hand to search among the crannies, under overhanging tree roots and in the tangled growth of water-weeds.

The stick should have various attachments, hooks, dredges, etc., and most important of all—a collecting bottle. One type should have a fixture whereby it can be firmly screwed into the ferrule end of the stick, as shown in the illustration, which will be found of good service in getting samples of water from places otherwise inaccessible. The method in using is to thrust the bottle, upside down, among a clump of weeds and then suddenly reverse it with a

quick motion and withdraw carefully ; thus bringing away some of the organisms found in the neighbourhood.

A quick method whereby many specimens can be caught, is to use a net made with a very fine mesh, but with the bottom cut to take the opening of a small bottle or phial. This is shown on the extreme right of the illustration. The net is immersed in the water so that the ring is just under the surface and is carefully drawn along with a slow motion. As the water strains through the mesh the organisms are left behind and are swept into the container.



When sufficiently concentrated the contents can be poured into a glass jar or other vessels and taken home. It is important to remember that air is necessary to the crowded occupants, so it would be a good plan, if the journey is more than an hour or so, to remove the corks now and again. When one has gained sufficient knowledge in naming specimens, each "dipping" can be kept in a separate jar, and a list of the occupants made. This is quite a useful work and can form a definite piece of scientific information.

For examination a glass trough of considerable size, say three inches in length, half an inch in depth, and two inches in height, should be half

filled with the water, and examined with the pocket magnifier. With a little practice it will be found easy to take up not only the larger organisms, but even very minute ones, with one of the dipping-tubes with a long tapering point already referred to. The organism, when "spotted," is followed by eye and tube, the finger being held over the mouth of the latter, and at the critical moment the finger is removed, and the organism swept into the tube by the in-rushing water. Now wipe off the excess with a clean handkerchief, "spot" the organism in the tube again, and carefully absorb the superfluous water with a piece of blotting paper; and finally, gently but sharply blow the remainder on to the plate of the live-box, put on the cover, and examine with an objective of  $1\frac{1}{2}$ -in. power. If, as often happens, the organism sticks to the side of the tube, a little more water must be drawn in, and the process repeated.

In the case of weeds, a small portion should be placed in the trough and carefully examined from end to end, a suitable piece then being removed to a smaller trough, of the type described in Chapter II, which can be placed on the microscope stage for better examination. Let us now consider the objects most likely to be met with.

A piece of stick may be coated with a white layer, feeling rough to the touch, and full of small holes. The chances are that this will be a piece of freshwater sponge, *Spongilla fluviatilis*, and by dark-field illumination particles of food material may be seen to enter at some orifices and be ejected at others. With a very high power and a very thin

section, properly prepared, these holes will be seen to be the mouths of channels which are lined by the most delicate organisms possible, each having a minute body crowned with a tiny crystal cup, in the middle of which is a long cilium, or flagellum, as it is here called (Plate XIII, Fig. 1). The currents are produced by the combined action of these flagella. In point of fact, the sponge is a colony of minute animals working harmoniously for the common good. If the specimen be found in winter the sponge will be full of tiny balls, the "gemmules" of the next season's growth. The roughness is due to the flinty spicules, which are at once the scaffolding and the protection of the sponge. By boiling the sponge in a mixture of nitric acid and water (half and half) these spicules will be set free, and may be washed, allowed to settle, washed again, dried, and mounted in balsam. The gemmules are coated by very beautiful spicules, consisting of two wheels connected by a rod. These may be treated in the same way.

Perhaps the lowest form of life is the *Amœba*, shown in Plate IX, Fig. 1, a mere lump of jelly, which flows along, and when it comes into contact with any likely subject for digestion flows round it, absorbs what it can for nutriment, and leaves the remainder behind. A near relative of the amœba is the *Arcella* (Fig. 2), which is simply an amœba with a shell. Being unable to swim, these organisms are naturally found at the bottom of the collecting bottle, and it is always advisable to take up a portion of the debris with a dipping tube, which is then held upright on a

slide with the finger upon it until the dirt settles on to the slide; a cover-glass can then be placed over the deposit and examined in the usual way. Many forms will be discovered by this method which would otherwise escape observation.

Another curious organism, though much larger in size, is the sun animalcule (*Actinophrys*), which has a round body and long tentacles (Fig. 3), to which free-swimming organisms adhere, and by the combined action of the neighbouring ones are drawn to the body and received into it; one cannot say swallowed.

Fig. 6, Plate IX, shows the curious process whereby the infusoria multiply by division, a groove appearing at one point, rapidly deepening, and finally separating the animal completely into two. The species is the *Chilodon*, a flattened creature, ciliated all over, having a set of teeth arranged in the form of a tube, and at its fore-part a kind of membranous lip. A similar phenomenon, in an earlier stage, is shown in Fig. 26, Plate XIII, the organism in this case being *Euplotes*.

It has been said that sponges are colonies of extremely minute organisms, each furnished with a membranous collar or funnel, the whole looking like an exquisite wine-glass without a foot. These organisms are not, however, always grouped in colonies. Many are free-growing, and may be found attached to the stems of water-plants, but they are extremely minute, and will hardly be noticed. Perhaps all that will be seen will be a tiny pear, with a straight line, the margin of the cup, on each

side of its summit. The flagellum will be quite invisible.

Some similar organisms may, nevertheless, be found which, though still minute, are within the range of a properly managed  $\frac{2}{3}$  in. objective. One example, and of extreme beauty, is the *Dinobryon* shown in Plate XIII, Fig. 3. Each "zoöid," as the separate animals are called, among the infusoria, or each generation of zoöids, stands upon its parent and has two flagella. When alarmed, the zoöid sinks to the bottom of its cell, and withdraws its flagella. In Fig. 2 (*Euglena*) we have a similar zoöid, but of far greater size, and free-swimming. It is a very common object, and possesses a red eye-speck close to the "contractile vesicle." All infusoria have the latter, some a great number, as in Fig. 9. The vesicle contracts at regular intervals and is then simply blotted out, but re-forms in the same place, so that it can be compared, although only approximately so, with the action of the heart in maintaining a circulation.

The lovely rosette shown in Fig. 4 is the *Synura*, a spherical colony of zoöids, each of which has two flagella, and is in addition clothed with rows of cilia. A beautiful sight it is to watch these colonies rolling through the field of view. Not uncommon, especially in brackish water, is the *Peridinium* (Fig. 5), with its plate armour, long flagellum, and girdle of cilia. A gigantic species of the same family is common in sea-water, and will be easily recognized by its body, not much larger than that of *Peridinium*, being furnished with three long arms, curiously bent. It is called

*Ceratium*, and is sometimes present in such abundance as to thicken the water, near the surface of which it swims.

We now come to a class of infusoria which is characterized by the possession of a complete covering of cilia, arranged in rows all over the body. The number of these is enormous; we can only glance at a few types, by mastering which the observer will, at all events, know whereabouts he is. The first we will take is the *Coleps* (Fig. 6), a very common kind, whose body is marked by a series of geometrical lines, so that the organism looks very much like an elongated geographical globe. These markings are on the tunic, which is of a brownish colour. Very different is the *Trachelocerca* (Fig. 7), with its long flexible neck, which is in constant movement from side to side as the creature swims along. As seen in the figure, the neck is clear and the head has a fringe of longer cilia.

The *Trachelius* (Fig. 8) is perhaps the largest of all the infusoria, being readily visible to even an inexperienced eye. Its body is richly furnished with contractile vesicles, and the protoplasm is curiously reticulated. We may here remark that the *Trachelius* is especially prompt in doing what most of these organisms do when put under pressure in a live-box, namely, in performing a kind of *hara-kiri*. The outline first becomes irregular, then the body rapidly swells and finally comes to pieces, the fragments dancing mockingly away under the influence of their still-moving cilia. The remedy is to use the cotton-wool trap and the lightest possible pressure.

A very elegant organism is shown in the bottom right-hand corner of the Plate (Fig. 25). It is the *Loxophyllum*, and has a strongly marked contractile vesicle.

Another large form is *Amphileptus* (Fig. 9), already referred to as having a large number of contractile vesicles arranged in a regular row; and more massive still is *Bursaria* (Fig. 10), a very curious organism, very much like a purse indeed, and possessing a wonderful arrangement of cilia inside the funnel. These are arranged like a ladder, a series of rows of short stiff cilia, which move at short intervals in unison, and tend to sweep down into the cavity any small particles of food. This arrangement is here described for the first time, and appears to be quite unlike anything else among the infusoria.

One of the most beautiful of all these forms is shown in Fig. 11, *Folliculina*, a type of a large group characterized by the possession of a transparent case, of extremely elegant form, within which the animal retreats on the slightest alarm.

Fearless and independent, as becomes its size, is the trumpet-shaped *Stentor* (Fig. 12), which may easily be seen when present, as it is in almost every good gathering of water-weed. The particular form drawn (*S. polymorphus*) does not make a case, but many members of the genus do, and it is very common to see a stem almost covered with them. Such a sight, once seen under dark-field illumination, will never be forgotten. The method of multiplication of the *Stentors* (by division) is extremely easy to watch, and very instructive.

A curious organism is *Trichodina* (Fig. 13), which, though a free-swimmer, is always parasitic upon the body of some higher animal. We have found it sometimes upon hydra, and always in hundreds upon the stickleback. The next group of infusoria is distinguished by the body's being only ciliated at particular points, usually round the mouth, or what acts as such. The first form is *Vorticella* (Fig. 14), a beautiful vase-like creature upon a stem. Down the stem runs a muscular fibre, and on the least shock the fibre contracts and draws the stem into a beautiful spiral, whilst the cilia are drawn in, and the zoöid assumes the appearance of a ball at the end of a watch-spring. It is truly a wonderful sight to see a whole colony of these little creatures bobbing up and down, as it only needs one member of the family to touch another to start the sensitive contraction working.

Many compound tree-like forms of *Vorticella* are known, one of which, *Carchesium* (Fig. 15), may serve as a type of all. In the case of this organism, the colony contracts in sections on a moderate shock; in the second, *Zoothamnium*, as a whole; whilst in *Epistylis* the stalks are rigid, and the individuals contract singly. When the shock is violent, the appearance presented by the two former is that shown in Fig. 16. In all three cases the colonies are usually so large that they are visible as trees to the naked eye, and some members of the group are extremely common. Moreover, they are often parasitic, as, for example, upon cyclops, which is frequently loaded with them.

Another compound form is *Ophrydium*, a colony

of which (not unusually large) is shown of the natural size in Fig. 18, with a single zoöid, magnified, by the side of it, in Fig. 19.

Lastly, we have an exquisite group of organisms related to *Vorticella*, but possessing a transparent envelope, the forms of which are most varied, but always graceful. *Vaginicola* (Fig. 17) is a good example of this, and *Cothurnia* (Fig. 20) still more so. Many of these organisms, too, are furnished with a plate, attached either to the head or to the body, which plate, when they withdrew into their cases, closes the latter perfectly, as in the case of the *Pyxicola* (Fig. 21).

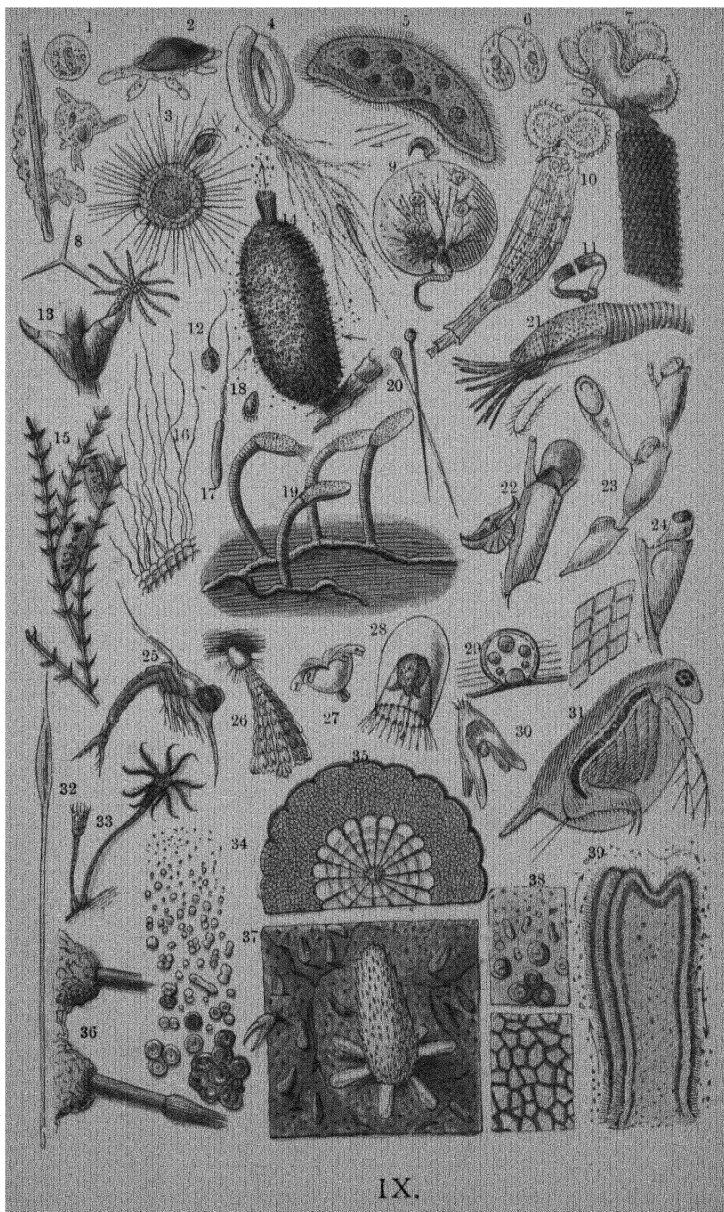
A very interesting but singularly obtrusive organism is the *Stylonychia* (Figs. 22, 23). How often has it happened to us to have an interesting object nicely in the field of view, and then to have it knocked out of sight by the blundering incursion of this burly fellow, who runs so rapidly by means of his "styles" that he gives nothing time to get out of the way. He is of interest to us, however, as the representative of a class in which the body is not ciliated, or very partially and slightly so, usually round the mouth. We have frequently found *Stylonychia*, in company with *Vorticella* and *Paramacium* (Plate IX, Fig. 5), in the water in which flowers have been standing for a few days; sometimes the numbers are so great as to make the water quite milky.

One more form must conclude this short sketch of the great infusorial family. It is the *Acineta* (Fig. 24), which, attached by its foot-stalk, and devoid of cilia, patiently waits, with outspread arms,

## IX

### FIG:

1. Amœba
2. Arcella
3. Sun animalcule
4. Miliolina
5. Paramœcium
6. Chilodon subdividing
7. Melicerta ringens
8. Spicula of Sponge, Grantia
9. Noctiluca miliaris
10. Rotifer vulgaris
11. Do. jaws
12. Sponge animalcule
13. Sertularia operculata
14. Sponge, Grantia
15. Sertularia operculata, with ovicells
16. Actinia, showing weapons
17. Do. base of weapon more magnified
18. Sponge granule, ciliated
19. Anguinaria anguina
20. Spicules of sponge from Oyster Shell
21. Head of Snake-headed Zoophyte
22. Bugula avicularia
23. Polyzoön, Eretea
24. Do. Notamia
25. Young of Crab
26. Hydra tuba
27. Medusa, cast off from above
28. Naked-eye Medusa, Thaumantias
29. Compound Eye, Medusa
30. Larva, Snake Star
31. Water Flea
32. Serpula, Pushing Pole
33. Comatula, early stage of Starfish
34. Carbonate of Lime, artificial
35. Sea Urchin, transverse section of spine
36. Serpula, bundle of spears
37. Sunstar, part of skin
38. Oyster shell in different stages
39. Cilia on mussel





to receive and embrace smaller members of the family as they dance merrily about.

The reader will find the group of organisms that has just been described, one of the most enchanting of all the astonishing creatures revealed by the microscope. The incredible vitality with which each and all are endowed must seem strange indeed to those who hitherto have been in ignorance of their existence. It is no exaggeration to say that one feels an affection towards them after half an hour's study. The private lives of a few species are seen in a drop of water, but to attempt to realize the multitude that is distributed wherever fresh water is found only bewilders. And everyone is full of beauty and interest!

It is common when examining infusoria to see much larger creatures with the appearance of small shrimps; these together with allied forms are dealt with in Chapter XI.

## CHAPTER IX

Hair and Fibrous Materials—Scales of Fish—Feathers—Structure of the Skin, Bone, and Teeth—Muscles, Nerves, and Ligaments—Blood Corpuscles—Circulation of the Blood.

AN inexhaustible range of objects is obtainable from the individual parts of the vertebrate or backboned animals. The student is well advised to pay attention to these as later on he will find how useful the knowledge is in accurately determining the species of animal under investigation. The structure must be known before the action of the various organs can be understood.

The hairs of all animals make fascinating examples for the microscope, and much can be learnt regarding their respective qualities when used as materials for clothing. On Plate VIII, Fig. 22, is a portion of human hair as it appears when splitting at the extremity. Fig. 23 is another and Fig. 24 shows the detail of a hair that has turned white. The cells may be seen extending down its centre and the peculiar roughened surface around the circumference is clearly visible.

In the sheep's wool (Fig. 30) this structure is much more developed, and gives to the fibres the "felting" power that causes them to interlace so firmly with each other, and enables cloth—when really made of wool—to be cut without unravelling. Fig. 37 is the smooth hair of the badger; Fig. 34

is the curious hair of the red deer, which looks as if it had been covered with a delicate net.

Fig. 28 is the soft, grey, wool-like hair of the rat ; and Fig. 29 is one of the long dark hairs that project so plentifully, and form the glistening brown coat of that animal. Fig. 38 is the knobbed hair of the long-eared bat, the knobs being formed of protuberant scales that can easily be scraped off. Fig. 31 shows a hair of the common mole ; and Fig. 32 is one of the long hairs of the rabbit. Fig. 27 is a flat hair of the dormouse, slightly twisted, the difference in the breadth showing where the twist has taken place. The hair of the mouse is beautifully ribbed, so as to look like a ladder. Fig. 26 is one of the very long hairs that so thickly clothe the tiger moth caterpillar ; and Fig. 25 is a beautifully branched hair taken from the common humble bee.

Most gorgeous colours may be obtained by examining hairs with the use of polarized light ; how this can be done is explained in the next chapter.

The four fibres mostly used in the manufacture of clothing materials are : wool, Fig. 30, which has already been described ; linen, Fig. 39 ; cotton, Fig. 40 ; and silk, Fig. 41. The structure of each is very well marked and easily made out with the microscope ; so that an adulterated article can readily be detected by a practised eye. Cotton is the most common adulteration of silk and linen fabrics, and may at once be detected by its flat twisted fibre. Silk is secreted by a pair of glands from the silk-worm (the caterpillar of the moth, *Bombyx mori*), and is therefore composed of two parallel threads. If the threads are not quite parallel the silk is

considered of poor quality. Silken fibre is always covered, when new, with a kind of varnish, usually of a bright orange colour, which gives the undressed "floss" silk its peculiar hue, but which is soluble and easily washed away in the course of manufacture.

Figs. 35 and 36 are the small and large hairs of that magnificent creature, the sea mouse (*Aphrodite aculeata*), whose covering, although it lies in the mud, glows with every hue of the rainbow, and in a brilliant light is almost painfully dazzling to the eye.

The scales of some of the fishes are shown on Plate VIII, in order to exhibit their mode of growth by successive layers. The scales are always enveloped in membranous sacs, and in some cases, as in the eel, they do not project beyond the surface, and require some little observation to detect them. A scale of an eel is shown on Plate XI, Fig. 14, and is a magnificent object under polarized light. Fig. 33 is a scale of the greenbone pike; and Figs. 42 and 43 are scales of the perch, showing the roots by which they are held in their places. The roach, dace, bleak, and many other similar fish have a beautiful silvery substance on the under surface of the scales, which make beautiful objects under the microscope. The scales of a fish constitute a record of the individual, and there is much of interest concerning this point that may be read in the books on the subject.

More examples of hairs, and other processes from the skin, together with the structure of the skin

itself, of bone, of blood, and the mode in which it circulates, are given on Plate X.

In all important points of their structure the feathers of birds are similar to the hairs of animals, and are developed in a similar manner. They are all composed of a quill portion, in which the pith is contained, and of a shaft, which carries the vane, together with its barbs. The form of each of these portions varies much, even in different parts of the same bird, and the same feather has almost always two kinds of barbs; one close and firm, and the other loose, floating, and downy. If a small feather be plucked from the breast or back of a sparrow or any other small bird, the upper part of the feather is seen to be close and firm, while the lower is loose and downy, the upper part being evidently intended to lie closely on the body and keep out the wet, while the lower portion affords a soft and warm protection to the skin.

Fig. 12, Plate X, shows the feather of a peacock, wherein the barbs are very slightly fringed and lie quite loosely side by side. Fig. 18 is part of the same structure, in a duck's feather, wherein are seen the curious hooks which enable each vane to take a firm hold of its neighbour, the whole feather being thus rendered firm, compact, and capable of repelling water. The reader will not fail to notice the remarkable analogy between these hooks and those which connect the wings of the bee.

Fig. 17 is a part of the shaft of a young feather taken from the canary, given for the purpose of showing the form of the cells of which the pith is composed. Fig. 20 is part of the down from a

sparrow's feather, showing its peculiar structure ; and Fig. 21 is a portion of one of the long drooping feathers of the cock's tail.

Fig. 13 exhibits a transverse section of one of the large hairs or spines from the hedgehog, and shows the disposition of the firm, horn-like exterior, and the arrangement of the cells. Sections of various kinds of hair are interesting objects, and are easily made by tying a bundle of them together, soaking them in gum, hardening in spirit, and then cutting thin slices with a razor. A little glycerine will dissolve the gum, and the sections of hair will be well shown. Unless some such precaution be taken, the elasticity of the hair will cause the tiny sections to fly in all directions, and there will be no hope of recovering them.

Several examples of the skin are also given. Fig. 27 is a section through the skin of the human finger, including the whole of one of the little ridges which are seen upon the extremity of every finger, and half of two others. The cuticle, epidermis, or scarf-skin, as it is indifferently termed, is formed of cells or scales, much flattened and horny in the upper layers, rounder and plumper below. The true skin, or "cutis," is fibrous in structure, and lies immediately beneath, the two together constituting the skin, properly so called. Beneath lies a layer of tissue filled with fatty globules, and containing the glands by which the perspiration is secreted.

One of the tubes or channels by which these glands are enabled to pour their contents to the outside of the body, and, if they be kept perfectly

clean, to disperse them into the air, is seen running up the centre of the figure, and terminating in a cup-shaped orifice on the surface of the cuticle. On the palm of the hand very nearly three thousand of these ducts lie within the compass of a square inch, and more than a thousand in every square inch of the arm and other portions of the body, so that the multitude of these valuable organs may be well estimated, together with the absolute necessity for keeping the skin perfectly clean in order to enjoy full health.

Fig. 1 shows a specimen of epidermis taken from the skin of a frog, exhibiting the flattened cells which constitute that structure, and the oval or slightly elongated nuclei, of which each cell has one. In Fig. 32, a portion of a bat's wing, the arrangement of the pigment is remarkably pretty. Immediately above, at Fig. 31, is some of the pigment taken from the back of the human eyeball. The shape of the pigment cells is well shown. Similar specimens may easily be obtained from the back of a sheep's eye which has been hardened in spirit, or from that of a boiled fish. Fig. 33 shows the pigment in the shell of the prawn.

On various parts of animal structures, such as the lining of internal cavities, the interior of the mouth, and other similar portions of the body, the cells are developed into a special form, which is called "epithelium," and which corresponds to the epidermis of the exterior surface of the body. The cells which form this substance are of different shapes, according to their locality. On the tongue,

for example (for which see Fig. 11), they are flattened, and exhibit their nucleus, in which the nucleolus may be discovered with a little care. Cells of this kind are rounded, as in the case just mentioned, or angular, and in either case they are termed squamous (i.e. scaly) epithelium. Sometimes they are like a number of cylinders, cones, or pyramids, ranged closely together, and are then called cylindrical epithelium. In some circumstances the free ends of cylindrical epithelium are furnished with a number of vibrating filaments or cilia, and in this case the structure is called "ciliated" epithelium. Cylindrical epithelium may be found in the ducts of the glands which open into the intestines, as well as in the glands that secrete tears; ciliated epithelium must be sought in the windpipe and the interior of the nose. A specimen taken from the nose is seen at Fig. 15. A beautiful example of ciliated epithelium is to be found in the gills of the mussel. A portion of one of the yellowish bands which lie along the edge of the shell on the opening side is carefully removed with sharp scissors, and examined in the shell-liquor, being protected from pressure by placing a piece of paper beneath each end of the cover-glass. Such a preparation is shown in Plate IX, Fig. 39, but no drawing can give an idea of its wonderful beauty and interest. The cilia will continue to move for a long time after removal from the shell.

That most important material, bone, of which the skeleton of all vertebrate animals is mainly constructed, is illustrated by several examples on Plate X.

Fig. 9 is a good example of human bone, and is a thin transverse section taken from the thigh. When cut across, bone exhibits a whitish structure filled with little dottings that become more numerous towards the centre, and are almost invisible towards the circumference. When placed under a microscope, bone presents the appearance shown in the illustration.

The large aperture in the centre is one of innumerable tubes that run along the bone and serve to allow a passage to the vessels which convey blood from one part of the bone to another. They are technically called Haversian canals, and if a longitudinal section be made they will be found running tolerably parallel, and communicating freely with each other. Around each Haversian canal may be seen a number of little black spots with lines radiating in all directions, and looking something like flattened insects. These are termed bone-cells or "lacunæ," and the little black lines are called "canaliculi." In the living state they contain cells which are concerned in the growth of the bone, and these may be made evident by softening fresh bone with acid, cutting sections of it, and staining. When viewed by transmitted light the lacunæ and canaliculi are black; but when seen by dark-field illumination the Haversian canals become black, and the lacunæ are white.

As these canaliculi exist equally in every direction, it is impossible to make a section of bone without cutting myriads of them across; and when a high power is employed they look like little dots scattered over the surface. A very pretty object

can be made of the bone taken from a young animal which has been fed with madder, as the colour gets into the bone and settles chiefly round the Haversian canal. A young pig is a very good subject, so is a rabbit. Fig. 16 is a similar section cut from the leg-bone of an ostrich.

The development of bone is beautifully shown in Fig. 30, a delicate slice taken from a pig's rib. Above may be seen the gristle or cartilage, with the numerous rows of cells; below is the formed bone, with one of the Haversian canals and its contents; while between the two may be seen the cartilage-cells gathering together and arranging themselves into form. The cartilage-cells are well shown in Fig. 28, which is a portion of the cup which had contained the eye of a haddock.

The horn-like substances at the end of our fingers, which we call the nails, are composed of innumerable flattened cells. These cells are generally so fused together as to be quite indistinguishable even with a microscope, but can be rendered visible by soaking a section of nail in *liquor potassæ*.

When examining vegetable life we have seen that plants are built up of cells. This is also the case with animals although the cells are not so variable in shape. Nuclei, two or more being often found in a single cell, are generally more pronounced; in many cases the nucleoli too are visible. Good examples may be obtained from the yolk of an egg.

The teeth have many of the constituents of bone, and when prepared for examination are seen to consist of a hard substance, called enamel, which coats their upper surfaces, of dentine, or ivory,

within the enamel, and of "cement," which surrounds the fangs. In Fig. 26, Plate X, which is a longitudinal section of the human "eye" tooth, is seen the ivory occupying the greater part of the tooth, coated by the enamel at the top and the cement at the bottom. In the centre of each tooth there is a cavity, which is plentifully filled with a pulpy substance by which the tooth is nourished. A transverse section of the same tooth is seen in Fig. 25.

The enamel is made of little elongated prisms, all pointing to the centre of the tooth. When viewed transversely, their ends are of a somewhat hexagonal shape, something like an irregular honeycomb. The dentine is composed of a substance pierced with myriads of minute tubes. They require a rather high power—the  $\frac{1}{6}$  in. objective—to show them properly. The cement is found at the root of the fangs, and is best shown in the tooth of an aged individual, when it assumes very clearly the character of bone.

Sections may be made by sawing a slice in the required direction, polishing one side, and cementing it with Canada balsam to a slide. It may then be filed down to nearly the required thinness, finished by carefully rubbing with a hone, and polished with buff leather. Canada balsam may then be dropped upon it, and a glass cover pressed firmly down.

Fig. 29 is a section cut from one of the palate teeth of the ray (*Myliobates*).

A rather important element in the structure of animals is the "elastic ligament," which is found in the back of the neck and other parts of the body,

especially about the spine. It is made of a vast number of fibres of variable shape and length, branching and communicating, arranged generally in bundles, and remarkable for containing very few vessels, and no nerves at all. At Fig. 14 may be seen an example of this elastic ligament, which is called in some parts of the country by the name "paxwax," taken from the neck of a sheep. It is designed to support the head and an example can be pulled out with a little dexterity. It has remarkable powers of stretching, and if a piece is suspended and weighted to extend it several times its length, it will, when dry, retain its extension.

The white fibrous tissue by which all the parts of the body are bound together is seen at Fig. 10 ; and at Fig. 22 is a beautiful example of the "ultimate fibres" of the crystalline lens of a sturgeon's eye.

The muscles of animals are of two kinds, the one termed the striped, and the other the unstriped. Of these, the latter belongs to organs which work independently of will, such as the stomach, etc., while the former belongs to those portions of the body which are subject to voluntary motion, such as the arm and the leg. The unstriped muscle is very simple, consisting merely of long spindle-shaped cells, but the striped or voluntary muscle is of more complex construction. Every voluntary muscle consists of myriads of tiny fibres, bound together in little bundles, enveloped in a kind of sheath. Fig. 24 is an example of this muscular fibre, taken from beef. When soaked in spirit, it often splits into a number of discs, the edges of which are marked by the transverse lines.

A fibre of nerve is drawn at Fig. 23, and is given for the purpose of showing the manner in which the nerve is contained in and protected by its sheath, just like a telegraph-wire in its coverings. Just above is a transverse section of the same fibre, showing the same arrangement from another point of view, and also illustrating the curious phenomenon, that when nerve-fibres are treated with carmine the centre takes up the colouring matter, while the sheath remains white as before. The best way of studying nerves is to decapitate a frog, and cut off a piece of one of the nerves, which, like fine silk threads, come out between the joints of the spine inside the abdomen. By careful teasing out, using the Borradaile needles, it is easy to obtain preparations showing all the above points, and, in addition, the folding-in of the internal sheath which corresponds to the insulators of a telegraph-line.

The blood of animals can be compared with the sap of plants, but differs greatly from it under the microscope. In sap there seem to be no microscopic characters, except that when a branch is cut, as in the vine, the flowing sap may contain certain substances formed in the wounded cells, such as chlorophyll, starch, and raphides ; but the blood is known to be an exceedingly complex substance both in a microscopic and a chemical point of view. When a little fresh blood is placed under the microscope, it is seen to consist of a colourless fluid filled with numerous little bodies, commonly called " blood-globules," varying greatly in size and shape, according to the animal from which they were

taken. Those of the reptiles are very large, as may be seen at Fig. 4, Plate X, which represents a blood corpuscle of the *Proteus*. In this curious reptile the globules are so large that they may be distinguished during its life by means of a common pocket lens.

In the vertebrated animals these corpuscles are red, and give to the blood its peculiar tint. They are accompanied by certain colourless corpuscles, spherical in form, which are sometimes, as in man, larger than the red globules, and in others, as in the newt, considerably smaller. The general view of the red corpuscles has sufficient character to enable the practised observer to name the class of animal from which it was taken, and in some cases they are so distinctive that even the genus can be ascertained with tolerable certainty. In point of size, the reptiles have the largest and the mammalia the smallest, those of the *Proteus* and the musk-deer being perhaps the most decidedly opposed to each other in this respect.

In shape, those of the mammalia are circular discs, mostly with a concave centre, though the camel has oval ones; those of the birds are more or less oval and convex; those of the reptiles are decidedly oval, very thin, and have the nucleus projecting; and those of the fishes are oval and mostly convex. During the process of coagulation the blood corpuscles run together into a series of rows, just as if a heap of pence had been piled on each other and then pushed down, so that each penny overlaps its next neighbour.

These objects are illustrated by six examples on Plate X. Fig. 2 is human blood, showing one of

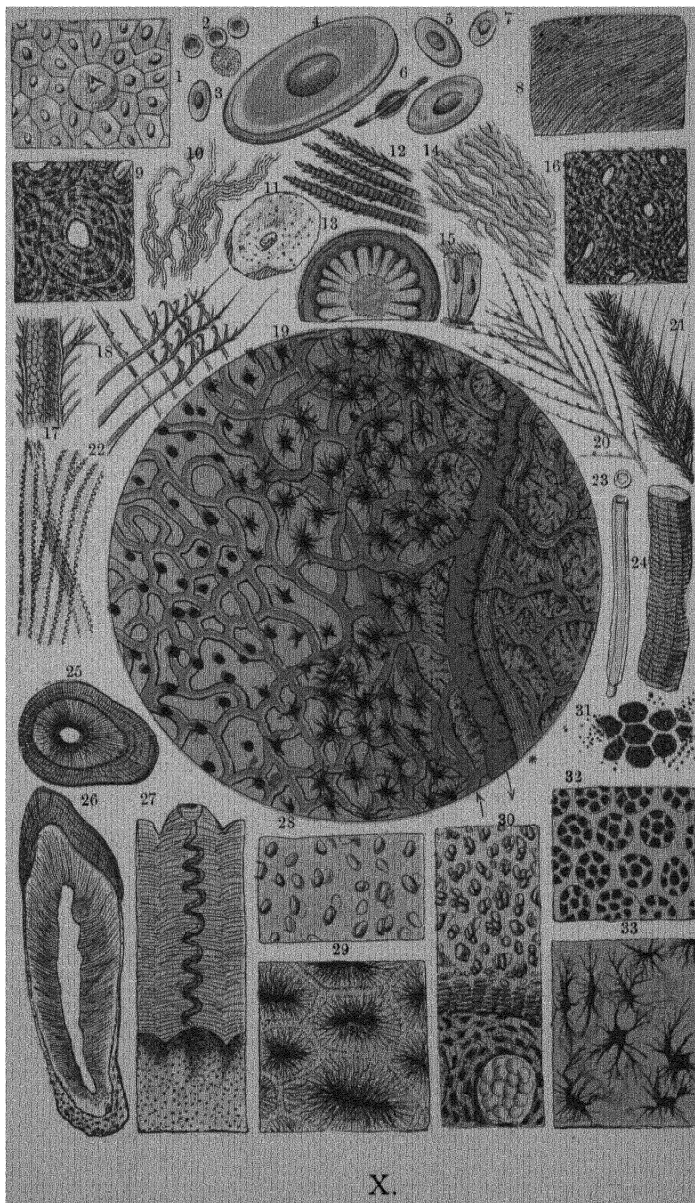
the white corpuscles ; Fig. 3 is the blood of the pigeon ; Fig. 4, of the *Proteus anguinus* ; Fig. 5, of the tortoise ; Fig. 6, of the frog, showing the projecting nucleus ; and Fig. 7, of the roach. The blood possesses many curious properties, and a full account must be sought for in the books dealing with histology.

In the centre of Plate X is a large circular figure representing a portion of the membrane of a frog's foot as seen through the microscope, and exhibiting the circulation of the blood. The mode of arranging the foot so as to exhibit the object without hurting the frog is simple enough.

Take an oblong slip of wood—my own was made in five minutes out of the top of a cigar-box—bore a hole about an inch in diameter near one end, and cut a number of little slits all round the edge of the wooden slip. Then get a small linen bag, put the frog into it, and dip him into water to keep him comfortable. When he is wanted, pull one of his hind feet out of the bag, draw the neck tight enough to prevent him from pulling his foot back again, but not sufficiently tight to stop the circulation. Have a tape fastened to the end of the bag, and tie it down to the wooden slide. Then fasten a thread to each of his toes, bring the foot well over the centre of the hole, stretch the toes well apart, and keep them in their places by hitching the threads into the notches on the edge of the wooden strip. Push a glass slide carefully between the foot and the wood, so as to let the membrane rest upon the glass, and be careful to keep it well wetted. If the frog kicks, as he will most likely do, pass a

## FIG:

1. Skin, Frog
2. Blood, Human
3. Do. Pigeon
4. Do. Proteus
5. Do. Tortoise
6. Do. Frog
7. Do. Roach
8. Human nail
9. Bone, Human
10. White fibrous tissue
11. Epithelial cells from tongue
12. Feather, Peacock
13. Spine, Hedgehog, transverse section
14. Paxwax, Sheep
15. Epithelial cells from nose
16. Bone, Ostrich
17. Feather, shaft of Canary's
18. Do. Wild Duck
19. Circulation of blood, Frog's foot
20. Feather, Sparrow
21. Do. Cock's tail
22. Fibre, crystalline lens of fish
23. Nerve
24. Muscle, Meat
25. Tooth, transverse section
26. Do. longitudinal section
27. Skin of Human finger, sweat duct
28. Eye of Haddock
29. Myliobates, section of palate teeth
30. Gristle, Pig
31. Pigment, Human eye
32. Do. Wing of Bat
33. Do. Shell of Prawn





thin tape over the middle of the leg, and tie him gently down to the slide.

Bring the glass into focus, and the membrane will present the appearance so well depicted in the engraving. The veins and arteries are seen spreading over the whole of the surface, the larger arteries being often accompanied by a nerve, as seen in the illustration. Through all these channels the blood continually pours with a rather irregular motion, caused most probably by the peculiar position of the frog. It is a most wonderful sight, of which the observer is never tired, and which seems almost more interesting every time that it is examined.

It is amusing as well as instructive to watch the corpuscles steering their way along the vessels, but remember it is not so to the frog so, as soon as you can, return the frog to the field.

The tails of young fish also afford excellent objects under the microscope, as the circulation can be seen nearly as well as in the frog's foot. The gills of tadpoles can also be arranged upon the stage with a little care, and the same organs in the young of the common newt will also exhibit the circulation in a favourable manner.

## CHAPTER X

Wonders of the Seashore—Foraminifera—Radiolaria—Hydroid Zoophytes—Polyzoa—Marine Worms—Mollusca—Advantages of Polarized Light.

ALTHOUGH the enthusiastic pond-hunter has a great range of objects for the microscope, there is indeed a larger field to be explored in the sea. The sponges, polyzoa, hydroids, crustacea, mollusca, not to mention the algæ, are all astonishingly enchanting.

Whether it be along the edge of the water, as the tide retreats, or in the rock-pools; or, perhaps best of all, upon those portions of the shore left uncovered only by the lowest spring-tides, the harvest is simply inexhaustible. Stones turned up will exhibit a world in miniature. Encrusted with green or pink sponges, or with gelatinous masses of ascidians, fringed at its edges with hydroids, coated above with polyzoa, a single one will often supply more work than could be got through in a week of steady application.

A description of the freshwater sponge already given may serve very well to indicate the general outlines of the organization of the marine ones too. The spicules of the latter are, however, not always flinty; very often, as in the case of *Grantia* (Plate IX, Figs. 8 and 14), they are calcareous, a point which can be settled by the application of a little nitric acid and water. If lime be present there will be

strong effervescence, and the separation of the spicules can only be effected by gently warming a portion of the sponge in caustic potash solution, pouring the resulting mass into water, and allowing the spicules to settle. The washing and settling must be repeated several times, and a portion of the deposit may then be taken up with a dipping-tube, spread upon a slide and dried, and then covered in balsam solution. The forms are endless, and the same sponge will often supply three or four, or even more. Among them may be seen accurate likenesses of pins, needles, marlin-spikes, cucumbers, grappling-hooks, fish-hooks, knife-rests, fish-spears, barbed arrows, spiked globes, war-clubs, boomerangs, life-preservers, and many other indescribable forms. The flinty forms must be prepared by boiling, as described in speaking of the mounting of diatoms in Chapter XII, except that, of course, only one settlement is required after thorough washing.

Everyone who has been by or on the sea on a fine summer night must have noticed the bright flashes of light that appear whenever its surface is disturbed ; the wake of a boat, for example, leaving a luminous track as far as the eye can reach. This phosphorescence is caused by many animals resident in the sea, but chiefly by the little creature represented at Fig. 9, the *Noctiluca*, myriads of which may be found in a pail of water dipped at random from the glowing waves. A tooth of this creature more magnified is shown immediately above.

A large group of microscopic organisms is known to zoologists under the name of foraminifera, on

account of the numerous holes in their beautiful shells which are mainly composed of carbonate of lime. The remains of countless numbers of foraminifera is a characteristic of a geological formation which indicates the presence of petroleum or rock-oil as it was originally called. The living animal within the shell is composed of a jelly-like substance ; this flows out of the holes and envelops any food material which happens to be near. Foraminifera are widely distributed, but perhaps the easiest way of finding specimens is to collect the muddy or sandy deposits by towing a small dredge from a boat near the seashore. The larger objects should be removed from the dredging and the remainder dried. If a handful of this material is then placed in a pail of clean water, stirred quickly, the " dead " shells having their cavities temporarily filled with air will float to the surface where they can be removed with a spoon and dried for examination. Many forms can be found on the shore in the sand ; the sand should be passed through a series of wire sieves of increasing fineness and the residuum in each case examined under a  $1\frac{1}{2}$  in. objective. The shells may be picked up with a fine sable-hair brush, and they may be mounted by sticking them to the slide with thin starch paste, putting on a cover-glass properly supported, and then running turpentine under the cover-glass, heating to expel the air, and finally filling up with balsam. Or, as opaque objects, they may be mounted in a cell dry. The forms are endless, but all are beautiful, and a few examples are given in Plate IX, Fig. 4 (*Miliolina*), and Plate XII, Fig. 7, which is a portion of the shell to

show the holes, Fig. 13 (*Polystomella*), Fig. 14 (*Truncatulina*), Fig. 15 (*Polymorphina*), Fig. 16 (*Miliolina*, partly fossilized), Fig. 18 (*Lagena*), and Fig. 20 (*Biloculina*).

Allied to these are the lovely radiolaria, whose shells, constructed on a similar plan, are composed of flint. They are found in remarkable profusion in the deposit from Cambridge, Barbados, but also in a living state at even enormous depths in the ocean. Many fine specimens may be purchased already mounted on slides.

The hydroid zoophytes are represented by several examples. These creatures are soft and almost gelatinous, and are furnished with tentacles or lobes by which they can catch and retain their prey. In order to support their tender structure they are endowed with a horny skeleton, sometimes outside and sometimes inside them, which is called the polypidom. They are very common on our coasts, where they may be found thrown on the shore, or may be dredged up from the deeper portions of the sea.

Fig. 13 (Plate IX) is a portion of one of the commonest genera, *Sertularia*, showing one of the inhabitants projecting its tentacles from its domicile. Fig. 15 is the same species, given to show the egg-cells. This, as well as other zoophytes, is generally classed among the sea-weeds in the shops that throng all watering-places.

The form just referred to is a near relative of the hydra, already described, and belongs to the same great family as the sea-anemones. One form, shown in Fig. 26, is the *Hydra tuba*, long thought

to be a distinct animal, but now known to be the young form of a jelly-fish, or medusa. It throws off joints at intervals, each of which becomes a perfect jelly-fish. One of them is shown in Fig. 27. Fig. 28 represents a very small and pretty medusa, the *Thaumantias*. When this animal is touched or startled, each of the purple globules round the edge flashes into light, producing a most beautiful and singular appearance. Fig. 29 exhibits the so-called compound eye of another species of medusa, though it would appear that these are really connected with the nervous system of the animal, and have to do with the pulsating contractions of the bell by which it is propelled through the water.

In my *Common Objects of the Seashore* the *Actiniæ*, or sea-anemones, are treated of at some length. At Fig. 16 is shown part of a tentacle flinging out the poison-darts by which it secures its prey ; and Fig. 17 is a more magnified view of one of these darts and its case.

Much more might be said under this head, but we must pass on to another group, which, whilst possessing a certain general resemblance to the hydroid zoophytes, differs utterly from them in internal organization. We have already referred to the freshwater polyzoa. The marine forms are vastly more numerous, and more easily found, since not only pieces of weed upon which they grow are to be found upon every beach, but whole masses of leaf-like colonies, forming what is known as horn-wrack, may be plentifully found. Instead of the tentacles armed with sting-cells, the polyzoa have arms clothed with active cilia, by which the food

is swept into the mouth, passing on into the stomach, and then through the intestine to another opening.

Fig. 19 is a very curious zoophyte called *Anguinaria*, or snake-head, on account of its shape, the end of the polypidom resembling the head of the snake, and the tentacles looking like its tongue as they are thrust forward and rapidly withdrawn. Fig. 21 is the same creature on an enlarged scale, and just below is one of its tentacles still more magnified. Fig. 23 is the ladies'-slipper zoophyte (*Eretea*); and Fig. 24 is called the tobacco-pipe or shepherd's-purse zoophyte (*Notamia*).

Fig. 22 is a portion of the *Bugula*, with one of the curious "birds'-head" processes. These appendages have the most absurd likeness to a bird's head, the beak opening and shutting with a smart snap (so smart, indeed, that the ear instinctively tries to catch the sound), and the head nodding backward and forward just as if the bird were pecking up its food. On Plate XII, Fig. 2, is a pretty zoophyte called *Gemellaria*, on account of the double or twin-like form of the cells; and Fig. 5 represents the *Antennularia*, so called on account of its resemblance to the antennæ of an insect. Fig. 22 is an example of a pretty zoophyte found parasitic on many sea-weeds, and known by the name of *Membranipora*. Two more specimens of zoophytes may be seen on Plate XI, as they appear under polarized light. Fig. 17 is the *Cellularia reptans*; and Fig. 20 is the *Bowerbankia*, one form of which occurs in fresh water.

Among the worms we may refer to the beautiful

little *Spirorbis*, whose tiny coiled spiral tube may be found attached to almost every sea-weed, and which, when placed in a trough of sea-water, sends forth its beautiful crown of plumes. In chalk or other soft rocks, again, the tubes of *Spio*, with its two long waving tentacles, may be found by hundreds. Then there are the centipede-like worms, which may be found under nearly every stone, and which belong to the great family of *Nereids*, provided with formidable jaws and stiff bristles of various forms. The *Serpulæ* are allied to the *Spirorbis* already mentioned. Parts of the so-called feet of one of these worms are shown in Fig. 36 (Plate IX), where the spears or "pushing-poles" are seen gathered into bundles, as during life. One of them, on a larger scale, is shown in Fig. 32.

In the sea the few species of crustacea which fresh water offers to the observer in the shape of cyclops and its allies become thousands, and their changes during development are numerous and puzzling. Who, for example, would suppose that the young stage of the cyclops was indistinguishable in habits, and almost in form, from that of the barnacle which adheres to the rocks? Yet such is the case, and there are other metamorphoses even more startling. Fig. 25 is the larva of the common crab.

The mollusca proper will not afford us many objects, except in the form of their lingual ribbon, which may be extracted from the mouth, gently heated in *liquor potassæ*, and mounted in balsam after well washing, when the rows of teeth form

splendid objects by polarized light. The palate of a whelk is shown in Plate XI, Fig. 19.

Again, the gills of the mussel will afford a beautiful illustration of ciliary action. If a portion of the thin plates which lie along the edge of the shell be examined in a little of the liquor, the action may be splendidly seen, and watched for a long time (Fig. 39).

The structure of shell, e.g. oyster-shell, is well shown in three examples: Fig. 34 is a group of artificial crystals of carbonate of lime; and on Figs. 38 and 39 may be seen part of an oyster-shell, showing how it is composed of similar crystals aggregated together. Their appearance under polarized light may be seen on Plate XI, Figs. 1 and 6.

We now pass on to the echinoderms, including the star-fishes and sea-urchins.

The old story of the goose-bearing tree is an example of how truth may be stranger than fiction. For if the fable had said that the mother goose laid eggs which grew into trees, budded and flowered, and then produced new geese, it would not have been less a stranger tale than the truth. Plate IX, Fig. 33, shows the young state of one of the common star-fishes (*Comatula*), which in its early days is like a plant with a stalk, but afterwards breaks loose and becomes the wandering sea-star which we all know so well. In this process there is just the reverse of that which characterizes the barnacles and sponges, where the young are first free and then become fixed for the remainder of their lives. Fig. 30 is the young of another kind

of star-fish, the long-armed *Ophiuris*, or snake-star.

Fig. 37 is a portion of the skin of the common sun-star (*Solaster*), showing the single large spine surrounded by a circle of smaller spines, supposed to be organs of touch, together with two or three of the curious appendages called pedicellariæ. These are found on star-fishes and bear a close resemblance in many respects to the bird-head appendages of the zoophytes. They are fixed on foot-stalks, some very long and others very short, and have jaws which open and shut regularly. Their use is doubtful, unless it be protective by their continual movements, preventing the spores of algæ, or the young of various marine animals, from effecting a lodgment on the skin. A group of pedicellariæ from a star-fish is shown on a large scale on Plate XII, Fig. 6, and Fig. 9 of the same Plate shows the pedicellariæ of the *Echinus*.

Upon the exterior of the sea-urchin, a vast number of spines can be seen, having a very beautiful structure, as may be seen by Fig. 35, Plate IX, which is part of a transverse section of one of these spines. An entire spine is shown on Plate XII, Fig. 12, and shows the ball-and-socket joint on which it moves, and the membranous muscle that moves it. Fig. 8 is the disc of the snake-star as seen from below. Fig. 1 is a portion of skin of the sun-star, to show one of the curious tubercles which are found upon this common star-fish. Fig. 3 is a portion of cuttle "bone," very slightly magnified, in order to show the beautiful pillar-like form of its structure; and Fig. 4 is the same object seen from

above. When ground very thin this is a magnificent object for the polariscope.

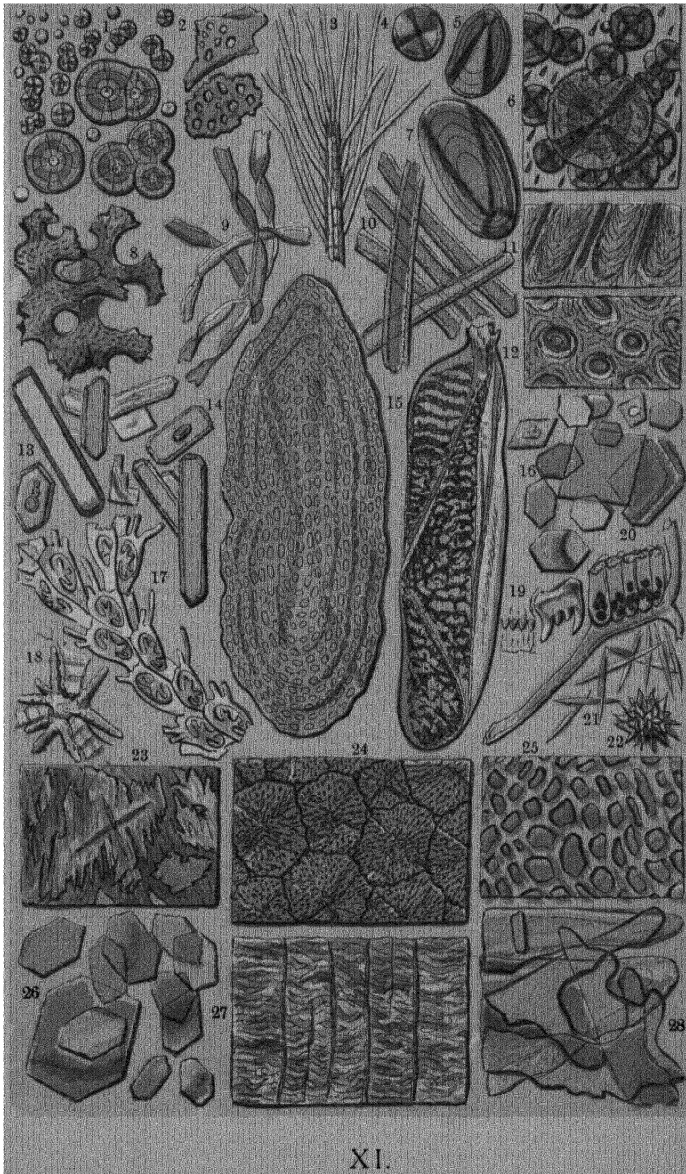
One or two miscellaneous objects now come before our notice. Fig. 11 is one of those curious marine plants, the corallines, which are remarkable for depositing a large amount of chalky matter among their tissues, so as to leave a complete cast in white chalk when the coloured living portion of the plant dies. The species of this example is *Jania rubens*.

Fig. 19 is part of the pouch-like inflation of the skin, and the hairs found upon the rat's tail, which is a curious object as bearing so close a resemblance to Fig. 22, the sea-mat zoophyte. Fig. 23 is a portion of the skin taken from the human finger, which has been injected with a coloured preparation in order to show the manner in which the minute blood-vessels or "capillaries" are distributed; and Fig. 26 is a portion of a frog's lung, also injected.

The process of injection is a rather difficult one, and requires considerable anatomical knowledge. The principle is simple enough, being merely to fill the blood-vessels with a coloured substance, so as to exhibit their form as they appear while distended with blood during the life of the animal. It sometimes happens that when an animal is killed suddenly without effusion of blood, as is often seen in the case of a mouse caught in a spring trap, the minute vessels of the lungs and other organs become so filled with coagulated blood as to form what is called a natural injection, ready for the microscope.

FIG:

1. Carbonate of Lime
2. Starfish
3. Thistle down
4. Starch, Wheat
5. Do. Potato
6. Prawn-shell
7. Starch, " Tous les mois "
8. Bone, cancellous
9. Gun-cotton
10. Cow's hair
11. Hoof, Donkey, longitudinal
12. Do. transverse
13. Nitre, Crystals
14. Scale, Eel
15. Wing, Water-Boatman
16. Chlorate of Potash, Crystals
17. Cellularia reptans
18. Star-shaped hair, Stalk of Yellow Water-Lily
19. Teeth, Palate of Whelk
20. Zoophyte, Bowerbankia
21. Raphides, i.e. crystalline formations in vegetable cells,  
Bulb of Hyacinth
22. Do. Rhubarb
23. Sulphate of Magnesia Crystals
24. Bone, Skate
25. Cherrystone, transverse section
26. Sugar, Crystals in honey
27. Tendon, Ox
28. Calcareous plates. Tooth of Echinus





Before leaving the subject I must ask the reader to refer again for a moment to the frog's foot on Plate X, and to notice the arrangement of the dark pigment spots. It is well known that when frogs live in a clear sandy pond, well exposed to the rays of the sun, their skins are bright yellow, and that when their residence is in a shady locality, especially if sheltered by heavy overhanging banks, they are of a deep blackish-brown colour. Moreover, under the influence of fear they will often change colour instantaneously. The cause of this curious fact is explained by the microscope.

Under the effects of sunlight the pigment granules are gathered together into small rounded spots, as seen on the left hand of the figure, leaving the skin of its own bright yellow hue. In the shade the pigment granules spread themselves so as to cover almost the entire skin and to produce the dark brown colour. In the intermediate state they assume the bold stellate form in which they are shown on the right hand of the round spots. Very remarkable forms of these cells may be found in the skin of the cuttle-fish.

Figs. 24 and 25 are two examples of coal, the former being a longitudinal and the latter a transverse section, given in order to show its woody character. Fig. 17 is a specimen of gold-dust intermixed with crystals of quartz sand, brought from Australia; and Fig. 21 is a small piece of copper-ore.

Every possessor of a microscope should, as soon as he can afford it, add to his instrument the beautiful apparatus for polarizing light. The

optical explanation of this phenomenon is far too abstruse for these pages, but the practical application of the apparatus is very simple. It consists of two prisms, one of which, called the polarizer, is fastened just below the stage; and the other, called an analyser, is placed above the eye-piece. In order to aid those bodies whose polarizing powers are but weak, a thin plate of selenite is generally placed on the stage immediately below the object. The colours exhibited by this instrument are gorgeous in the extreme, as may be seen by Plate XI, which affords a most feeble representation of the glowing tints exhibited by the objects there depicted. The value of the polarizer is very great, as it often enables observers to distinguish, by means of their different polarizing properties, one class of objects from another.

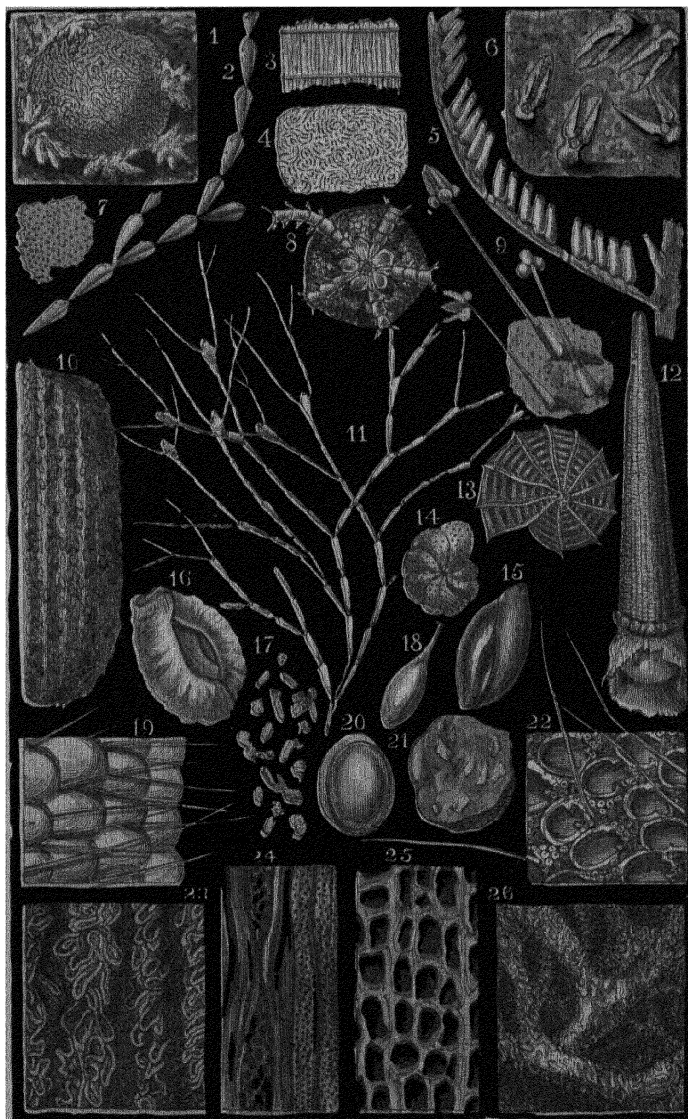
If the expense of a polarizing apparatus be too great for the means of the microscopist, he may manufacture a substitute for it by taking several thin plates of glass, a bundle of cover-slips will do, arranging them in a paper tube so that the light may meet the surface of the lowest one at an angle of about  $52^\circ$ , and placing the bundle above the eye-piece to act as an analyser; whilst, by using a plate of glass, and so arranging the lamp that the light falls upon it at the above angle, and is reflected up the tube of the microscope, he will find on rotating the extemporized analyser that the phenomena of polarization are to a great extent reproduced; whilst by splitting an extremely thin film from the surface of a sheet of mica, he will have a substitute for the selenite by means of which alone

can the gorgeous colour effects be produced. The extemporized apparatus will not, of course, give such perfect effects, but it will have served its purpose if it encourages the reader to explore further this interesting "side-show" of microscopy.

## XII

FIG:

1. Tubercle, Sun-star
2. Zoophyte, Gemellaria
3. Cuttle bone
4. Plate of ditto from above
5. Zoophyte, Antennularia
6. Pedicellariæ, skin of Starfish
7. Shell, Foraminifera
8. Snake-star, disc from below
9. Pedicellaria, Echinus
10. Wing-case, Weevil
11. Coralline
12. Spine, Echinus
13. Foraminifera, Polystomella
14. Do. Truncatulina
15. Do. Polymorphina
16. Do. Miliolina
17. Gold dust, with quartz
18. Foraminifera, *Lagena vulgaris*
19. Pouches, Skin of Rat's tail
20. Foraminifera, *Biloculina ringens*
21. Ore, Copper
22. Zoophyte, *Membranipora pilosa*, sea-mat
23. Human skin, injected
24. Coal, Longitudinal section
25. Do. Transverse section
26. Lung, Frog





## CHAPTER XI

Freshwater Worms—Planarians—Hydra—Rotifers—Water-flea  
—Water-bear.

THE freshwater worms form a large and well-defined group and a few words regarding them may be useful. They are very common and easily found. Because they are highly organized and transparent, the process of their life-history may be followed with ease and therefore makes an advantageous object for study.

One large group has the peculiarity of multiplying by division, the last segment being devoted to the formation of the new individual. At one time of the year the ordinary sexual process of reproduction takes the place of this method, and each worm is then surrounded by a belt such as may be seen in the common earthworm under similar conditions.

The type is the common *Nais*, which has a body of thirty segments or more, two eye-specks on the head and a double row of bristles along the back ; whilst below, each segment carries strong hooked bristles, nearly buried in the body, by means of which the worm crawls. Inside the mouth is a large proboscis, which can be protruded, and this leads into a stomach which is merely an enlargement of the intestine which succeeds it. The circulation of the blood (which is colourless) can

be easily watched. It begins at the tail with a contraction of the dorsal vessel, passes up to the head, and then down below the intestine to the tail again. The intestine is ciliated inside, and it is by a current of water carried into the intestine by these cilia that the blood is aërated.

In the next genus, *Dero*, this is clearly seen, for the tail (Plate XIV, Fig. 1) is opened out into a wide shield, from which rise four, six, or even eight finger-like processes. These parts are all ciliated, and contain a network of blood-vessels. The worm lives in a case which it builds in the mud, and the way to find it is to put some of the mud into a glass beaker with water, and allow it to stand. If there be members of this family in it, their tails will be seen protruding above the water. Pour out the mud sharply, fill up with water, and allow the dirt to subside; the worms may then be made to leave their cases by pressing with a sable-hair pencil on the lower end of the tube, and may be caught with the dipping-tube and placed in the live-box. They have no eyes, otherwise the general outline of the body closely resembles that of *Nais*.

*Slavina* (Fig. 2) has a row of touch-organs, like pimples, round each segment, and is a dirty looking creature, with an inordinately long first pair of bristles, but this organ reaches the height of its development in *Pristina* (Fig. 3) (sometimes, though wrongly, called *Stylaria*), which has three long sets of bristles upon the back, and keeps these in constant wing-like motion. The true *Stylaria* has a long trunk, set right in the head, and tubular (Fig. 6);

it grows to a considerable length, and when in the stage of fission it is very amusing to see the two proboscides waving about, one on the middle, as well as the original one at the head. There is also a form with a shorter proboscis of the same kind.

*Bohemilla* has a tremendous array of saw-like bristles upon the back, whilst *Chætogaster* has none at all in this position, and few below. *Æolosoma* has merely tufts of hair instead of bristles, and swims freely. It is easily recognized by the red, yellow, or green pigment spots in its skin, and by the ciliated head. Rarest of all the family is the one which connects it with the ordinary *Tubifex*, the red worm which lives in masses in the mud of brooks and ponds, the waving tails protruding above the water, and being instantly withdrawn when a foot is stamped upon the bank. Their cousin is *Naidium*, and has red blood, but multiplies by fission, which *Tubifex* does not.

Another group of worms is the *Planariæ*, small leech-like worms, black, white, or brown, which are rarely absent from a gathering. The would-be investigator will find in them an abundant field for work.

The great enemy of all these worms is the *Hydra*, a good idea of which may be formed from Plate IX, Fig. 13. There are three species, all of which are fairly common. They capture their prey in exactly the same way as sea-anemones and the marine hydroid forms, so numerous and varied.

Nor must we omit to notice the exquisitely beautiful Polyzoa, such as *Lophopus* (Plate XIV, Fig. 4), with its ciliated tentacles and transparent

social home ; *Fredericella* (Fig. 5), with its graceful stems, and their still more graceful inhabitants ; and the wonderful *Cristatella*, whose colonies form bodies which crawl over the stems of water plants. But for grace, beauty, and variety, the rotifers assuredly outshine all their fellow inhabitants of our ponds and streams.

We can only take a few types, and of all these the most easily found is the common rotifer (Plate IX, Fig. 10). It is there shown in the act of swimming, but it can withdraw its "wheels" and creep like a leech, protruding its foot as it does so. It is distinguished by the two eye-spots on the proboscis from *Philodina*, in which they are on the breast, and *Callidina*, which has none. When at ease in its mind, the animal protrudes its wheels, and by their action draws in particles of food, these passing down to the incessantly moving jaws, which act like a mill and crush the food before it passes on to be digested. The movement of the jaws may even be seen in the young rotifer whilst still in the egg within the body of the parent, and as the egg reaches its full development other eggs again are visible within it, so that we may have three generations in one individual. The males of most of the rotifera are unknown. Those that are known are very lowly organized, having only the ciliary wreath and the reproductive organs, and are only found at certain seasons of the year. We select a few individuals for illustration as types.

The common rotifer, already referred to, may be taken as the type of the leech-like class, so called from their mode of "looping" themselves along.

The group is a comparatively small one in comparison with the next, the free-swimmers. We can only select from the vast variety a few species, first of those classed as illoricated, from their being without a *lorica*, or case, and then of the loricated, which possess it. A very large and common form is *Hydatina* (Plate XIV, Fig. 7), which lives by choice in the reddish pools of water found often by the roadside. It shows the whole organization of the class magnificently; the ciliary wreath on the head with the striped muscles which draw the latter back, the powerful jaws, the digestive canal with its crop and intestine, the ovary with the developing eggs, the water-vascular system with the curious vibratile tags, and finally, the cloaca, which receives the waste of the body and expels it at intervals.

A specimen of *Hydatina senta* has been recorded as occurring in abundance in one of the lakes on Ross Island. Indeed, rotifers seem equally at home whether in tropical or polar regions. In very cold weather some species are frozen, but quickly revive when warmer conditions prevail. This power of overcoming climatic variation is apparent in many rotifers having the property of secreting a gelatinous covering in which they shelter until carried by the wind or other agency to a suitable abode.

Another form, also common, especially in clear water, is *Synchaeta* (Fig. 8), very much like a kite or peg-top in shape, which has the power of attaching itself by a glutinous thread, and spinning round at a tremendous rate. Then there is the gigantic *Asplanchna* (Fig. 9), which has no opening below, so that the waste must be discharged by the mouth;

and curious *Sacculus*, which gorges itself with chlorophyll until it looks like a green bag with a string round it, but clear and sparkling. Of the *Notommatae* there is a whole host, but we can only mention the beautiful *N. aurita* (Fig. 10), with an eye of a beautiful violet colour, composed of several spherules massed together, and two curious ear-like processes on the head, from which it takes its name. Some of the free-swimming rotifers have powers of leaping which must be noticed. The *Triarthra* (Fig. 11) has three arms, or what we may call such, which it can stretch out suddenly and leap to a considerable distance, whilst in *Polyarthra* the arms become a whole cluster of broad saw-like bristles.

We pass on to note a few species of the mail-clad or loricated rotifers, chief among which the great *Euchlanis* (Fig. 12), a noble-looking fellow, calls for our attention, his great size rendering him easily visible to the naked eye. It is difficult to avoid using the masculine gender, but, of course, all those figured and described are females. *Salpina*, too (Fig. 14), with its box-like lorica, armed with spines at each of the upper angles, and having three below, is quite easily recognized, and very common. *Brachionus* (Fig. 13) has a shield-shaped case, well furnished with spines, symmetrically arranged at the top, and an opening below for the flexible wrinkled tail, like the trunk of an elephant. *Pterodina* (Fig. 15) has a similar tail, but a round case, and the head is much more like that of the common rotifer when extended. *Anuræa* (Fig. 16), on the other hand, has no tail, and its case is shaped like a butcher's

tray, with a handle at each corner. *Dinocharis* (Fig. 17) has a roof-like case, with long spines on the root of the tail, and a forked stiff foot. *Noteus* (Fig. 18) is much like *Pterodina*, except in its foot, which more nearly resembles that of *Dinocharis*.

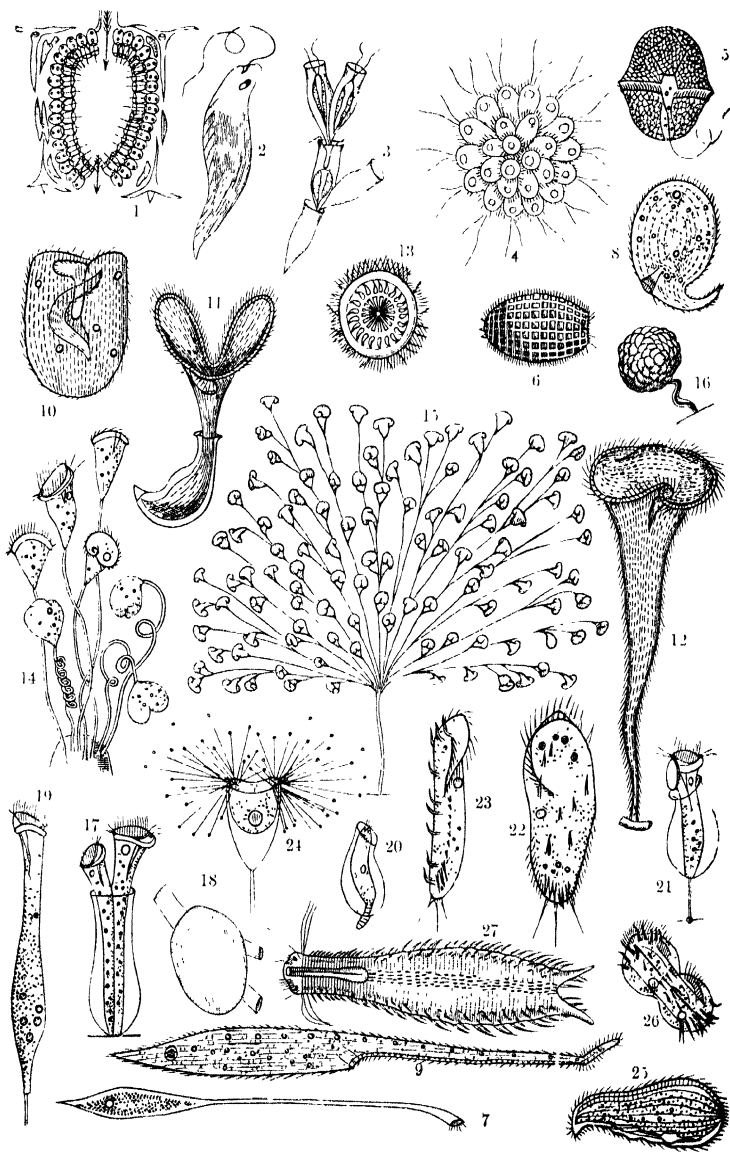
The list might be indefinitely extended, but sufficient has probably been said to enable the beginner to find his bearings in this large, beautiful and interesting class.

We pass on to notice in conclusion two or three of the fixed forms, of which a beautiful example is the *Melicerta ringens* (Plate IX, Fig. 7), whose building operations have a never-ending charm. Particles of debris are accumulated in a curious little cavity in the chin, in which they are whirled round, and mixed with a secretion which binds them together, and when a brick is made the head is bent down and the brick applied to the desired spot with mathematical regularity. By supplying fine particles of innocuous colouring matters, the *Melicerta* may be made to build a variegated case. A most remarkable specimen was once found in a jar from which over twenty different species of rotifer had already been taken. The water was collected by an inexperienced enthusiast, and there was only a pint of it. It had, moreover, been kept for three weeks, and the moral of that is, to preserve one's gatherings, and keep an aquarium into which they may be poured when done with for the moment. New forms will often develop with startling rapidity, their eggs having been present in the original gathering. The young form of *Melicerta*, shown in Plate XIV, Fig. 20, is strangely unlike its

### XIII

FIG.

1. *Grantia compressa*
2. *Euglena viridis*
3. *Dinobryon sertularia*
4. *Synura uvella*
5. *Peridinium tabulatum*
6. *Coleps hirtus*
7. *Trachelocerca viridis*
8. *Trachelius ovum*
9. *Amphileptus gigas*
10. *Bursaria Mülleri*
11. *Folliculina elegans*
12. *Stentor polymorphus*
13. *Trichodina pediculus*
14. *Vorticella nebulifera*
15. *Zoothamnium arbuscula*
16. Do. do. contracted
17. *Vaginicola crystallina*
18. *Ophrydium versatile* (colony)
19. Do. do. (single zooid)
20. *Cothurnia imberbis*
21. *Pyxicola affinis*
- 22-23. *Stylonychia mytilus*
24. *Acineta grandis*
25. *Loxophyllum meleagris*
26. *Euplotes charon* (dividing)
27. *Chætonotus larus*



*E. C. Bousfield del.*



mother, and much more nearly resembles its father.

Another group of extreme beauty is the *Flosculariæ* (Fig. 19), several species of which are very common. They will be easily known by their appearance, which resembles a shaving brush when closed; whilst, when opening, the shaving brush resembles a cloud of delicate shimmering threads, which at last stand out straight, radiating all round the head of the creature, and forming the trap by means of which it catches its prey. Finally, there is the lovely *Stephanoceros* (not, unfortunately, very common), with its five symmetrically placed and gracefully curved arms, perhaps the most lovely of all rotifers, with its exquisitely transparent body, sparkling with masses of green and golden brown. He who finds this has a treasure indeed, and will be encouraged to prosecute his studies.

Two irregular forms call for a word of remark. The first is *Chaetonotus* (Plate XIII, Fig. 27), which stands on the borderland of the infusoria and the rotifers, neglected as a rule by the students of both; and the second the *Tardigrada* (Plate XIV, Fig. 21), or water-bears, which have feet like those of the red wriggling larva of *Chironomus* (a gnat-like fly), whose silky tubes are common enough on submerged walls and on the stems of plants. These feet consist of a mass of radially arranged hooklets, which can be protruded or withdrawn at will; whilst the head of the water-bear is far more like that of a louse, pointed and hard, and suited for burrowing about, as the animal does, among the rubbish at the bottom of the bottle. Both the genera just referred

to will repay careful study, as little is known of their life-history or development.

A few words must be devoted, in conclusion, to the entomostraca, those shrimp-like animals which, like their marine relatives, act as scavengers to the community. Fig. 22 is a portrait of *Cypris*, a not very handsome form, but one very commonly found. Its shell is opaque, so that the internal organs are difficult to observe. Far different in this respect is the beautiful *Daphnia*, or water-flea (Plate IX, Fig. 31), whose carapace is of crystalline clearness, so that every movement of every one of the internal organs may be followed with the greatest facility. There are many species of the genus, and some of them are very common; so that the opportunity of examining these lovely objects is easily obtained. Plate XIV, Fig. 23, shows the most common of all the class under notice, the *Cyclops*, so named from the fact that, like the fabled giant of classical literature, it has a single eye in the middle of its forehead. It is often loaded with infusoria, especially *Vorticella* and *Epistylis*, already described, to such an extent that its movements are greatly hampered.

We have not space to figure more of these creatures, but other forms will be found not inferior in interest to those mentioned. The most curious of all are those which earn a dishonest and lazy living by attaching themselves to the bodies of other and larger animals, chiefly fish. One of the largest is the *Argulus*, the bane of aquarium keepers, which is of considerable size, and attacks gold-fish, and in fact almost any fish to which it can obtain access.

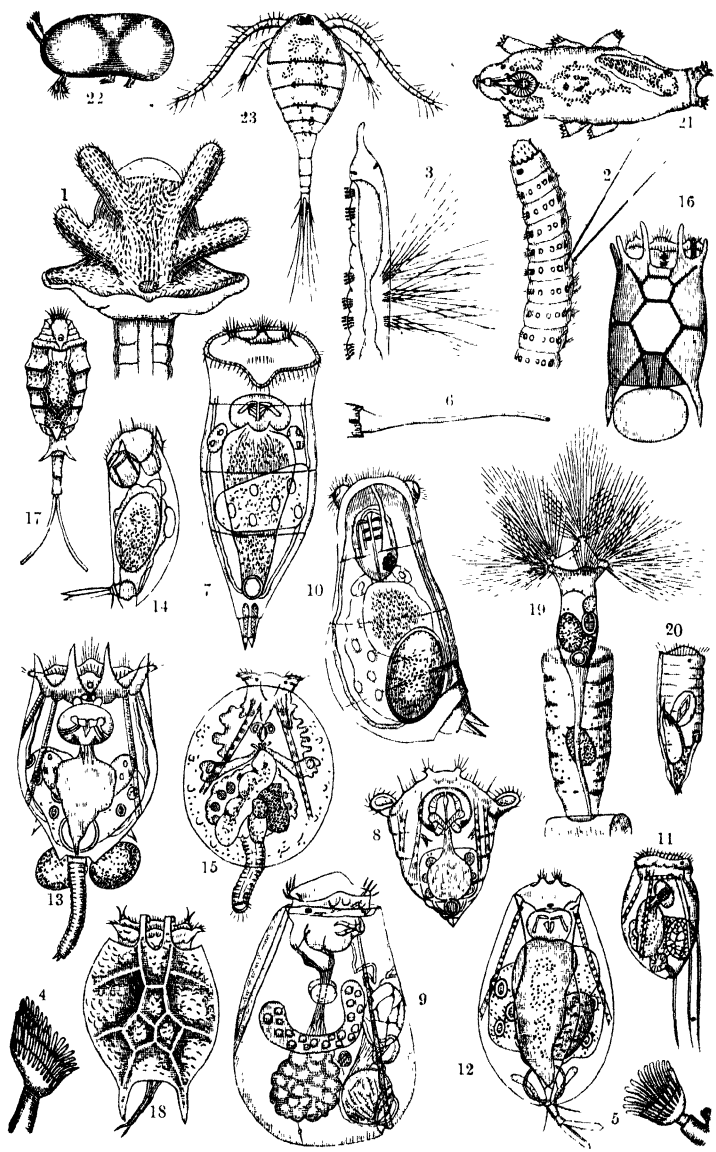
The gills of the stickleback will furnish examples of the curious *Ergasilus*, which consists chiefly of an enormous pair of hooks and two long egg-bags, the latter, in varying form, being carried by many of the entomostraca.

Upon the fins of the same fish will be found the remarkable *Gyrodactylus*, a worm-like animal which attaches itself by a large umbrella-like foot, in the centre of which are two huge claws. The head is split down the middle for some distance. We may mention, in concluding our notice of the external and involuntary guests of the unlucky stickleback, that its skin is usually frequented by hosts of the *Trichodina* described in Chapter VIII.

## XIV

FIG:

1. *Dero latissima*
2. *Slavina serpentina*
3. *Pristina longiseta*
4. *Lophopus crystallinus*
5. *Fredericella sultana*
6. *Stylaria proboscidea* (head)
7. *Hydatina senta*
8. *Synchoeta mordax*
9. *Asplanchna Brightwellii*
10. *Notommata aurita*
11. *Triarthra longiseta*
12. *Euchlanis triquetra*
13. *Brachionus amphiceros*
14. *Salpina mucronata*
15. *Pterodina patina*
16. *Anurœa brevispina*
17. *Dinocharis tetractis*
18. *Noteus quadricornis*
19. *Floscularia ornata*
20. Young *Melicerta*
21. *Tardigrada*
22. *Cypris fusca*
23. *Cyclops quadricornis*



*E. C. Bousfield ad nat del.*



## CHAPTER XII

Hints on the Preparation of Objects—Preservative Fluids—  
Mounting Media—Treatment of Special Objects—Section-  
cutting and Staining—Concluding Remarks.

THE microscopist who relies altogether on the dealer for his permanent preparations may expend a good deal of money, but the satisfaction which he derives from his hobby will be very inferior to that experienced by the worker who endeavours to secure, for exhibition or for reference, specimens of the objects which he finds most interesting and instructive to himself.

It will be our endeavour in the following pages to give a summary of the elementary principles upon which reliance is to be placed, though it must be clearly understood that the technique of the subject, already occupying a vast amount of literature, is extending day by day, so that it is impossible to deal exhaustively even with one single section of it. Reference must be made, for further information, to such publications as the *Journal of the Royal Microscopical Society*, or that of the Quekett Club, or to the monographs on the various departments.

Taking first the question of reagents, we may mention five which leave the cells of a tissue as nearly as possible in the natural condition, but fit for permanent preservation. The first of these, in

order of importance and of general applicability, is alcohol, represented for most purposes by industrial methylated spirit, which contains about 84 per cent of absolute alcohol, though, unfortunately for our purpose, there is a certain quantity of mineral naphtha in it in addition. This last has the effect of making it go milky upon dilution with water, which is a considerable disadvantage, though the milkiness disappears to some extent on standing, and it is rarely worth the while of the beginner to go through the formalities necessary to obtain permission to purchase unmineralized spirit. The ordinary "methylated" obtained from oil shops is useless for our purpose.

Four parts of methylated spirit with one of water forms the classical "70 per cent" alcohol, the most generally useful of all fluids for hardening and preserving purposes. A considerable quantity of this fluid should always be available.

Whatever other fluid may be used to begin with, spirit must almost always be used to finish the process, and fit the tissue for section-cutting and staining.

Of purely preservative, of fixative, fluids, we may mention "formalin," a 40 per cent solution of formaldehyde, which is rapidly coming to the front, as indeed it deserves to do. It is but slightly poisonous, if at all, and leaves in the tissue nothing which requires subsequent removal before proceeding to harden for section-work, whilst it is an admirable preservative of cell-form.

Another admirable but highly poisonous reagent is corrosive sublimate, in saturated solution, with 2 per cent of acetic acid.

A fourth is osmic acid, used in 1 per cent solution. This is a highly valuable reagent, but extremely expensive, very poisonous, and giving off fumes which are most irritating to the eyes.

The fifth, a very gentle, but in many respects



FIG. 24.

very satisfactory one, is picric acid in saturated solution. Tissues preserved in this medium must not be washed out with water, as it enters into very feeble combination with protoplasm, and the cells swell and disintegrate as the reagent is dissolved out.

Of mounting media we may mention glycerine,

glycerine jelly (made by dissolving starch in glycerine with the aid of heat), and Canada balsam, dissolved in xylol or benzole. The Canada balsam must be dried hard by evaporation over a water-bath, and dissolved as wanted. All these may be purchased from microscope dealers.

We will now proceed to go through the objects already referred to, and indicate the method of preservation.

For the study of the cell-structure of plants the portion to be examined is to be placed in spirit of about 30 per cent strength, which is changed after twenty-four hours for 40 per cent, after a further twenty-four hours for 55 per cent, and finally, as regards our present purpose, in 70 per cent spirit, in which it may remain until required for section-cutting. The effect of this treatment is to extract the bulk of the water from the tissue, with the minimum of shrinkage of the cells, the latter being preserved in their natural relations to surrounding parts.

In some cases, however, it is desirable to examine and preserve delicate structures, or parts, or dissections, in a medium which allows of the retention of the greater part of the natural moisture, and in such a case the tissue is immersed in glycerine diluted very much in the same way as the alcohol in the last process, but with very much longer intervals between the alterations of strength, until it reaches pure glycerine, in which it remains for a considerable time, as the exchange between the tissue and the dense fluid surrounding it goes on very slowly.

A combination of the two methods is also possible, the spirit-hardening being carried out for a portion of the time, and the tissue being thereafter transferred to glycerine, diluted or pure.

The object of using glycerine at all is merely that it has a much lower refractive index than balsam, so that delicate structures may sometimes be better seen in the former medium, but balsam is to be preferred wherever it is possible to use it, i.e. almost always. The harder portions of plants, woody stems, shells of fruit, or the like, require different treatment, and must, as a rule, be allowed to dry thoroughly before being cut.

Starch granules are somewhat troublesome to mount satisfactorily. The writer has tried many methods, and, on the whole, prefers a glycerin-gelatin medium, which keeps for an almost indefinite time, and may be made as follows: Thirty grains of gelatine (Nelson's "brilliant" or other transparent gelatine is to be preferred) are allowed to soak in water, and the swollen gelatine is drained, and dissolved in the water which it has absorbed, by the aid of a gentle heat. An equal bulk of pure glycerine is then added. In using, a small portion is transferred to a slide with the point of a knife and melted, a small quantity of starch granules added, and stirred into it with a needle. The cover-glass is then laid upon the still-fluid drop, pressed gently down so that the drop is extended to the margin of the cover, and the whole allowed to cool. It is then to be painted round with several layers of black cement.

Petals, or other parts of which it is desired to

obtain a surface view, must be mounted in cells, which may be made by the use of aluminium cell rings of suitable size, cemented to the glass slide. The slide must be free from grease, as the tissue must be fixed in position by the use of gum, and allowed to dry thoroughly before closing the cell, or the cover-glass will be bedewed with moisture when the cell is closed. The best plan is, after air-drying for a couple of days, to place the preparation on a metal plate over a beaker of boiling water for an hour or more, and then to close the cell immediately with black cement, maintaining the heat at first to ensure rapid drying, and then slowly withdrawing it. When cool, another coat should be given, and rather thick covers should be used, as these preparations are never required to be examined with high powers.

To mount pollen-grains, they should be sprinkled upon the surface of a slide which has been previously moistened with thin gum, and allowed to dry until it has become just "tacky"; the drying is then completed by gentle heat and a drop of balsam placed upon the grains, with a cover-glass over all. Bubbles will probably form, but with Canada balsam this is not of the slightest importance, as they always come out of their own accord, and balsam mounts should never be closed with cement of any kind until thoroughly dry.

Portions of many of the delicate algæ may be mounted in glycerine, having previously been soaked in it as already described; whilst the unicellular forms, such as desmids and diatoms, may be preserved in almost exactly the natural condition by

simply mounting them in a saturated solution of picric acid.

It is hardly necessary to say that, with such extremely fluid media, great care is required in closing the cell. A thin layer of marine glue should be first painted on, to secure the cover in position, and when this is thoroughly dry, several successive layers must be added in the same way. Glass slips with oval or round excavations in the centre can be purchased for this type of object thus making the mounting easier.

It may be said here, that it is advisable in all

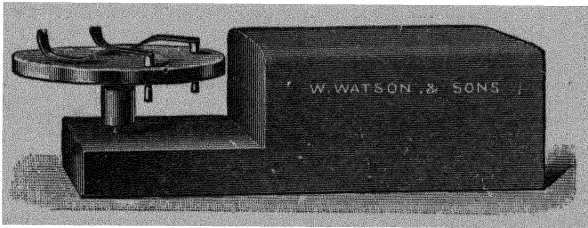


FIG. 25.

cases to use circular cover-glasses, as far as possible, as they lend themselves with great facility to a mechanically accurate closure. This slide is placed upon a turn-table, carefully adjusted until the cover is seen to be central when rotated, and a brush, preferably a small camel-hair pencil, charged with the desired fluid, but not in large excess, is held against the junction of the slide and cover, whilst the table is rapidly spun. A little experience will teach better than any description what amount of fluid there should be in the brush, and how thick the cement should be. If too thick, it will drag off

the cover ; if too thin, it will flow over the latter and over the slide.

The preparation of diatom-skeletons as permanent objects is easy. Consisting, as they do, of pure silix, or flint—i.e. practically glass—they resist long boiling in acids, so that there is little difficulty in isolating them from any organic matter with which they are mingled. It is generally recommended to treat them with strong nitric acid. This is a mistake. The acid acts much more powerfully and less violently when diluted with an equal bulk of water, and it is in an acid so diluted that portions of water-plants, or other diatomaceous material, should be boiled in a glass beaker until all the organic matter is dissolved. The beaker should be covered with a glass plate, to prevent dissipation of the acid fumes. When the process is complete, usually in about half an hour, the contents of the beaker are thoroughly stirred with a glass rod, poured rapidly off into a larger bulk of cold water, and allowed to settle for another half-hour. The process is then repeated with a smaller bulk of water, several times, to allow the removal of the last traces of acid, and finally with distilled water. The separation of the diatoms into grades is effected by settlement. The final result is poured into a tall glass vessel, and allowed to settle for, at first, a minute, the supernatant fluid again poured off, and allowed to settle for two minutes, and so on, the period being gradually increased, and each sediment preserved apart. The first will probably only be sand, but the proportion of diatoms will increase with each separation, though there will always be a

certain proportion of sand of such a size as to settle at the same rate as the diatoms. Marine plants especially will furnish a rich harvest by treatment as described.

A small portion of the deposit may now be spread thinly on a glass slide, allowed to dry thoroughly, be treated with balsam, and covered.

If it be desired to select individual diatoms, this must be done under the microscope, by means of a bristle fixed in a handle either with glue or sealing-wax. The diatom selected will adhere to the bristle if the latter be a trifle greasy, and should then be transferred to a slightly adhesive slide, coated either with thin solution of white shellac, or with thin gum nearly dry. When the forms desired are mounted, the preparation should be covered in balsam. The process is by no means as easily effected as described, however. But experience will breed dexterity.

The preparation of insects, or parts of insects, as microscopic objects is a tedious and difficult task. The main point is the trouble of softening the integument and eliminating the colour.

The latter can, in any case, be only partially effected. The beginner would do well to begin with a fairly easy form, such as the worker-ant. A good supply of these insects may be placed in a solution of caustic potash, and left there for at least some days until they begin to become clear and limp. From time to time a specimen may be taken, well washed with several waters, then with acetic acid and water of a strength of about 10 per cent, then with weak spirit, about 50 per cent. An attempt may then be made to arrange the

insect upon a slide, spreading out the legs so as to exhibit them to the best advantage, and when this has been done a cover-glass may be put on, supported in such a way as to prevent absolute pressure. The spirit is then withdrawn by means of a piece of filtering-paper cut to a point, and strong spirit added. This is again succeeded by a mixture of turpentine and crystal carboic acid in equal proportions, and finally the cover-glass is carefully lifted, and some thick balsam solution dropped on, the limbs finally arranged by means of warm needles, and the cover-glass carefully replaced



FIG. 26.

and pressed gently down by means of a clip, which may be obtained for a few pence. The whole is then set aside to harden, the deficiency caused

by evaporation made good, the balsam allowed to dry, and the preparation finally painted round. The finished slides should be labelled and placed in a store box. These can then be suitably indexed for future reference.

The contents of the body, in large insects, must be removed, and this is effected during the washing in water by gentle pressure with a camel-hair brush, the process being aided, if necessary, by a small incision made through the integument at the base of the abdomen.

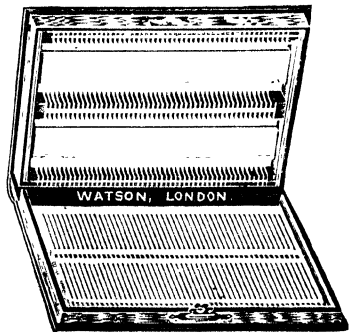


FIG. 27.

No method of examination can equal, for general usefulness, that of section-work. The relation of the parts to each other being preserved, it is possible to draw conclusions as to their actual relations which no other mode will allow.

The apparatus required is not necessarily expensive or complicated. Reduced to its elements, it consists essentially of some material to hold the section to be cut and a sharp razor to do it with. It is seldom, however, that such rough and ready methods will

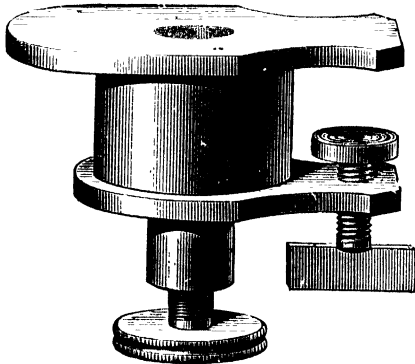


FIG. 28.

adequately serve the purpose, so a simple table microtome of the type illustrated should be purchased. This will leave the hands free for manipulation, and also will allow fine sections to be graded by the aid of the screw fitting seen at the lower portion of the figure.

Used in a simple manner, a carrot is shaped to fit the central hole, split down the centre so as to hold the object that is to be cut sandwiched between. This is then pushed gently into the hole and adjusted

so that the top is level with the brass plate. A sharp razor is then taken and a preliminary cut is made to smooth off the surface. The razor should be placed flat on the plate and moved across with a slanting motion. The screw is then turned; this will have the effect of raising the carrot a fraction upwards, and then another slice is taken. It will be found that this will adhere to the razor, but if it is dipped into some spirit the parts will separate and float off. The carrot is, of course, not wanted, but the section of the object, that was between, can be removed with a fine brush and placed on a glass slip for further examination. Much material of interest can be obtained in this way, stems, leaves, tender shoots, and so on will yield fine results.

Better sections can be made by using a wax mixture instead of the carrot, and at the same time some method of staining must be adopted in order to differentiate the structure. Perhaps the simplest, and certainly a very excellent one, is as follows. After the tissue which we propose to cut, has been passed from the hardening, or fixing fluid, into the successive alcohols, as previously described, it is placed in a solution prepared as follows: take about forty grains of carmine and eighty grains of borax, dissolve in about an ounce of water, add to the mixture an ounce of industrial methylated spirit, and let it stand for some time (about a week will be sufficient). To hasten the process of solution shake the mixture frequently and warm gently at intervals. Pour off the clear upper portion, and into this drop the block of tissue and allow it to remain until the fluid has thoroughly penetrated. Perhaps the best

plan is to substitute the carmine solution for the 55 per cent alcohol, and thus make the staining a stage in the hardening process. From the carmine solution the tissue is transferred to 70 per cent alcohol, to each ounce of which two drops of hydrochloric acid have been added, and after remaining in it for a day is placed in 70 per cent alcohol in two successive quantities. This can remain until ready and sections are needed; in the meantime tissue is becoming cleared of unwanted matter and structural parts becoming conspicuous because of the staining.

The next process is one of embedding, and for this paraffin wax is needed. The wax is melted by placing it in some form of container which can stand in a saucepan of boiling water. While this is being done, free the piece of tissue from superfluous spirit by drying on blotting paper for a minute or two. The melted wax is then poured into the hole of the microtome, the tissue is held on the end of a needle, lifted up and down in the wax until it is well covered, and then, before the mass solidifies, it is lowered into it and left to cool. When set this can be cut as previously described, though it would assist clean sections being made if the razor is dipped into spirit before cutting. The sections are then dropped into the strongest spirit solution on hand for two or three minutes, then passing on to a 70 per cent solution and again to a 50 per cent solution for a similar time, and finally on to the slide; a drop of balsam is placed on the section, and the cover-slip over all.

The simple method above detailed will answer

most ordinary purposes, provided that a few precautions be attended to. The chief are as follows. The piece of tissue, or whatever is being used for the making of an object, must be sufficiently dry for the melted paraffin wax to adhere to it. The razor must be extremely sharp and must be kept so by careful stropping. The blade must be drawn across the tissue from heel to point, and kept wetted with the spirit the whole time, so as to prevent any dragging of the section. The transference of the section to the slide must be effected by means of a section lifter, which may be made by beating out a piece of stout copper wire to a thin flat blade ; or a small palette-knife may be purchased. The various stages of alcohol solutions are best managed by using watch glasses and floating the section into them in the proper order with the aid of the lifter. The Canada balsam should be thin and the coverslip allowed to settle down into place without pressure.

In conclusion, do not be discouraged by failures, and take great care to prevent particles of dust contaminating your preparations or your instrument. This can only be achieved by careful filtration of all fluids and constant watchfulness. A preparation properly made will last for many years, and will amply repay all the pains that have been taken in its production by the pleasure that it will give.

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