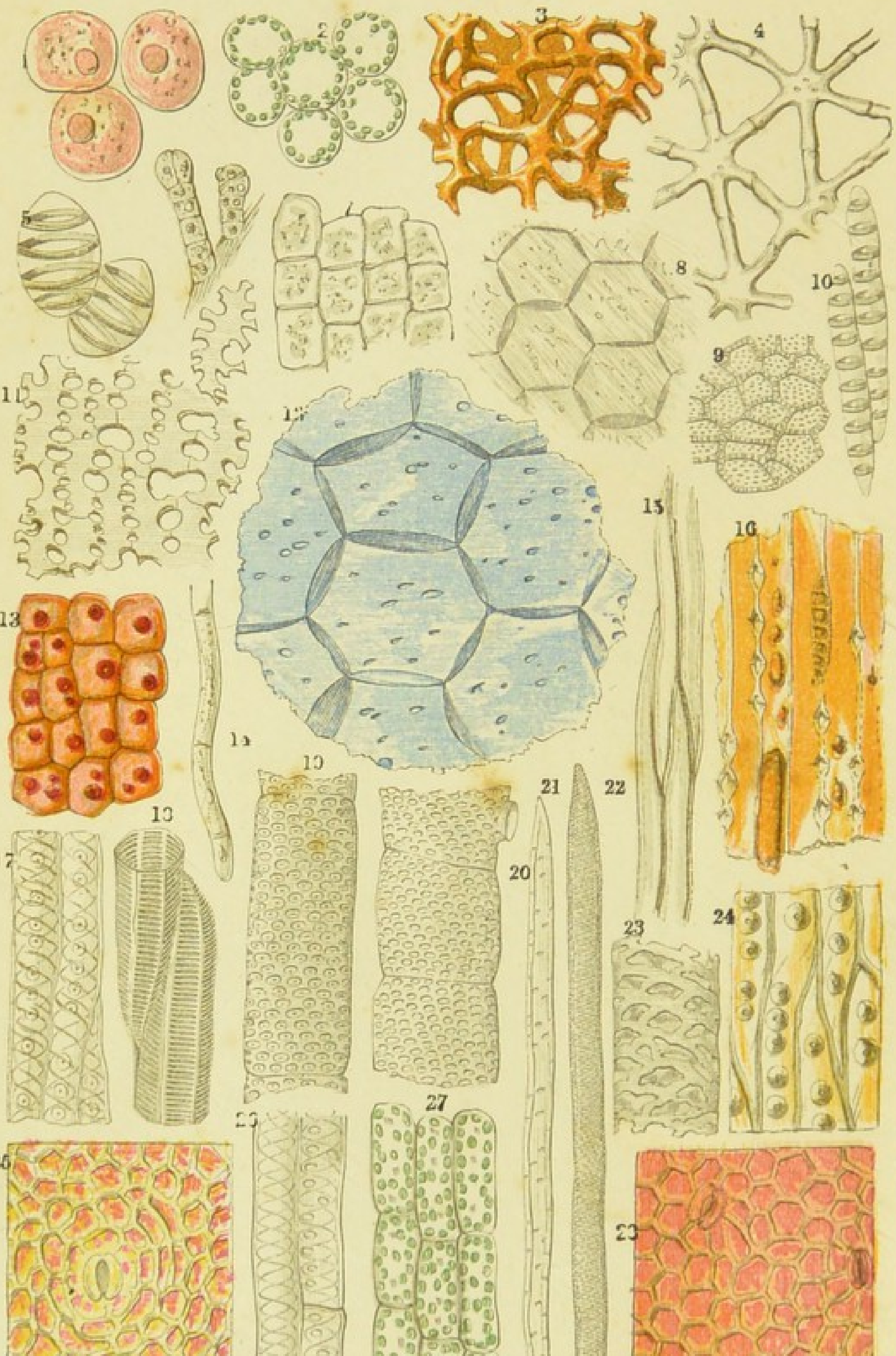


I.

COMMON OBJECTS

OF

THE MICROSCOPE

BY THE

REV. J. G. WOOD, M.A.

AUTHOR OF "THE ILLUSTRATED NATURAL HISTORY"

WITH UPWARDS OF FOUR HUNDRED ILLUSTRATIONS
BY TUFFEN WEST

LONDON
GEORGE ROUTLEDGE AND SONS, LIMITED
BROADWAY, LUDGATE HILL
MANCHESTER AND NEW YORK

PREFACE.

In my two previous handbooks, the "Common Objects" of the Sea-shore and Country, I could but slightly glance at the minute beings which swarm in every locality, or at the wonderful structures which are discovered by the Microscope within or upon the creatures therein described. Since that time a general demand has arisen for an elementary handbook upon the Microscope and its practical appliance to the study of nature; and in order to supply that want, this little volume has been produced.

I must warn the reader that he is not to expect a work that will figure and describe every object which may be found on the sea-shore or in the fields, but merely one by which he will be enabled to guide himself in microscopical research, and avoid the loss of time and patience which is almost invariably the lot of the novice in these interesting studies. Upwards of four hundred objects have been figured, including many representatives of the animal, vegetable, and mineral kingdoms, and among them the reader will find types sufficient for his early guidance.

Neither must he expect that any drawings can fully render the lovely structures which are revealed by the microscope. Their form can be given faithfully enough, and their colour can be indicated; but no pen, pencil, or brush, however skilfully wielded, can reproduce the soft, glowing radiance, the delicate pearly translucency, or the flashing effulgence of living and ever-changing light with which God wills to imbue even the smallest of his creatures, whose very existence has been hidden for countless ages from the inquisitive research of man, and whose wondrous beauty astonishes and delights the eye, and fills the heart with awe and adoration.

Owing to the many claims on my time, I left the selection of the objects to Mr. Tuffen West, who employed the greater part of a year in collecting specimens for the express purpose, and whose well-known fidelity and wide experience are the best guarantees that can be offered to the public. To him I also owe many thanks for his kind revision of the proof-sheets. My thanks are also due to Messrs. G. and H. Brady, who lent many beautiful objects, and to Messrs. Baker, the well-known opticians of Holborn, who liberally placed their whole stock of slides and instruments at my disposal.

THE MICROSCOPE.

CHAPTER I.

INTRODUCTION—USES OF THE MICROSCOPE—VALUE OF CAREFUL OBSERVATION—EARLY DISCOVERIES—EXTEMPORIZED INSTRUMENTS.

In the following pages I propose to carry out, as far as possible, with regard to the Microscope, the system which I have previously followed in the "Common Objects of the Sea-Shore and Country," and to treat in a simple manner of those wonderful structures, whether animal, vegetable, or mineral, which are found so profusely in our fields, woods, streams, shores, and gardens. Moreover, I intend to restrict my observations wholly to that class of instrument which can be readily obtained and easily handled, and to those supplementary pieces of microscopic apparatus which can be supplied by the makers at a cost of a few shillings, or extemporized by the expenditure of a few pence and a little ingenuity on the part of the observer. As in the former works, ordinary and familiar English terms will in every case be used where their employment is possible; but as, on account of their extremely minute dimensions, no popular name has been given to very many objects, we must be content to accept the more difficult language of science and render it as little abstruse as possible.

Within the last few years, the microscope has become so firmly rooted among us, that little need be said in its praise. The time has long passed away when it was held in no higher estimation than an ingenious toy; but it is now acknowledged, that no one can attain even a moderate knowledge of any physical science without a considerable acquaintance with the microscope and the marvellous phenomena which it reveals. The geologist, the chemist, the mineralogist, the anatomist, or the botanist, all find the microscope a useful companion and indispensable aid in their interesting and all-absorbing researches, and, with every improvement in its construction, have discovered a corresponding enlargement and enlightenment of the field displayed by the particular science which they cultivate.

But even to those who aspire to no scientific eminence, the microscope is more than an amusing companion, revealing many of the hidden secrets of Nature and unveiling endless beauties which were heretofore enveloped in the impenetrable obscurity of their own minuteness.

No one who possesses even a pocket-microscope of the most limited powers can fail to find amusement and instruction, even though he were in the midst of the Sahara itself. There is this great advantage in the microscope, that no one need feel in want of objects as long as he possesses his instrument and a sufficiency of light.

Many persons who are gifted with a thorough appreciation of nature in all her vivid forms are debarred by the peculiarity of their position from following out the impulses of their beings, and are equally unable to range the sea-shore in search of marine creatures or to traverse the fields and woods in the course of their investigations into the manifold forms of life and beauty which teem in every nook and corner of the country. Some are confined to their chambers by bodily ailments, some are forced to reside within the very heart of some great city, without opportunities of breathing the fresh country air more than a few times in the course of the year; and yet there is not one who may not find an endless series of Common Objects for his microscope within the limits of the tiniest city chamber. So richly does nature teem with beauty and living marvels, that even within the closest dungeon-walls a never-failing treasury of science may be found by any one who knows how and where to seek for it.

It is rather a remarkable fact, that the real value of observation is often in inverse ratio to the multitude of the objects examined; and we all know the extreme interest which attaches itself to minute and faithful records of the events which take place in some very limited sphere. For example, the annals of an obscure village in Hampshire have long risen into a standard work, merely by virtue of the close and trustworthy observations made by a resident in the place; the Tour round a Garden has enchanted thousands and proved quite as attractive as any tour round the world could be made; and many most curious and valuable original observations now committed to my note-book were made by an old lady in her daily perambulation of a little scrap of a back yard in the suburbs of London, barely twelve yards long by four wide.

The world-famous labours of Huber on the Honey-Bee, Lyonnet on the Goat Moth, and Strauss Durckheim on the Cockchaffer, are familiar to every student of zoology, and have done more towards advancing the study of animal life than hundreds of larger works which embrace thousands of species in their scope. There is little doubt but that if any one with an observant mind were to set himself to work determinately merely at the study of the commonest weed or the most familiar insect, he would, in the course of some years' patient labour, produce a work that would be most valuable to science, and enrol the name of the investigator among the most honoured sons of knowledge. There is not a mote that dances in the sunbeam, not a particle of dust that we tread heedlessly below our feet, that does not contain within its form mines of knowledge as yet unworked. For if we could only read them rightly, all the records of the animated past are written in the rocks and dust of the present.

Up to this time the powers of the microscope, as indeed is the case with all scientific inventions, are but in their infant stage; and though we have obtained instruments of very great perfection, it must be remembered, that many of the earliest and greatest discoveries were made with common magnifying glasses, such as are now sold for a few pence, and which would be despised by the generality of microscopical observers. Indeed, there are few instances where a person so minded may not possess himself of a microscope that will do a considerable amount of sound work and at an inappreciable cost. Many of my readers will doubtlessly have purchased one of those penny microscopes, composed of a pill-box and a drop of Canada balsam, which are hawked about the streets by the ingenious and deserving manufacturer; and upon a pinch, a very respectable microscope may be extemporized out of a strip of card, wood, or metal, and a little water.

There are, indeed, few branches of science which admit of such varied modes of handling as the use of the microscope. No two practical microscopists ever set about their work in the same manner; each will have his own special method of manipulation, which he thinks superior to any other, and each will arrive at most valuable results, though by different and sometimes opposite roads. The scope which it gives to ready invention is unlimited. Exigencies are continually occurring, when the observer is deprived for the time of some valuable adjunct, and is forced to invent and manufacture on the spur of the moment an efficient, though perhaps unsightly substitute. So well do some of these make-shift contrivances answer their purpose, that the inventor often prefers them to the more elegant and expensive articles which are purchased from the optician.

For example, I once patched up an extemporized dissecting microscope out of an old retort-stand, a piece of cane, and six inches of elder branch, which did its work as effectually as the shining-lackered brass instrument which it was intended to imitate. Moreover, by a very simple addition of a piece of wire, it answered as a movable stand for a camera lucida, thus performing a duty which would not have been achieved by the expensive brass microscope of the optician. All kinds of subsidiary apparatus may, in like manner, be made by any one who really cares about the beautiful pursuit in which he is engaged; and it is a matter of no light importance to those whose purses may not be overstocked, and whose hearts fail them at the price-lists of the opticians, that a great proportion of the adjuncts to the microscope may be manufactured at the cost of a very few shillings, where the regular makers charge many pounds.

The greater part of the imposing and glittering paraphernalia which decorate the dealer's counter or the table of the wealthy amateur may be replaced by apparatus that can be made at a very trifling cost from the most ordinary materials, and, for a while at least, the remainder may be dispensed with altogether. It is not the wealthiest, but the acutest and most patient observer who makes the most discoveries, for a workman is not made, nor even known by his tools, and a good observer will discover with a common pocket-magnifier many a secret of nature which has escaped the notice of a whole array of *dilettanti* microscopists, in spite of all their expensive and accurate instruments.

It is for those who desire to be of the former class that this little work is written, and in the course of the following pages many examples will be given, where a slight exertion of thought and ingenuity has been found equivalent to the purchase of costly and complicated apparatus.

CHAPTER II.

SIMPLE AND COMPOUND MICROSCOPES—MEASUREMENT OF POWER—HINTS FOR EXAMINATION—DISSECTING MICROSCOPE—KNIVES, SCISSORS, AND NEEDLES—DISSECTING TROUGHS—ARRANGEMENT OF ARTIFICIAL LIGHT—INSTRUMENT MAKING—DIPPING TUBES—CODDINGTON LENS—COMPOUND MICROSCOPE AND APPARATUS.

MICROSCOPES may be divided into two classes, Simple and Compound. The former class may contain several lenses or glasses, and generally consists of a single lens; but the Compound Microscope must consist of at least two glasses, the one near the object to be examined, and the other near the eye. We will first mention one or two forms of the Simple Microscope.

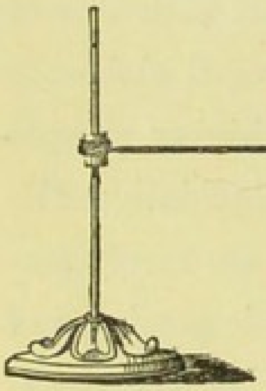
For all general purposes, the intending observer can do no better than supply himself with a common pocket-magnifier, which can be bought at any optician's for a very small sum, containing one, two, or three lenses, the last-mentioned being the most advisable. These lenses, or "powers" as they are technically called, vary in their magnifying capacities, those which increase the size of the object to the greatest degree being the smallest of size and the most decided in their convexity, and are required to be held nearest to the object.

In a work of this character it will be useless to waste time and space by mentioning the abstruse problems by which the construction of microscopes is governed, as the full account of them would more than occupy the entire book, and a compressed description would be wholly impossible. Suffice it to say that all those who desire to study the beautiful science of optics, and its application to the microscope, may find full information in the larger and more scientific works to which this little book is intended merely as an introduction.

According to this plan, I will here mention that the power of any lens is known by the distance at which it must be held from the object. Thus, the inch power of a compound microscope will magnify an object about forty times, while the quarter-inch magnifies not less than two hundred. Among microscopists the degree to which objects are magnified is always designated by "diameters," so that if an object be magnified ten diameters, we mean that it appears ten times as long and as broad as it really is. The reader must bear this in mind, for the glowing descriptions of magnifying powers that are so often seen in advertisements are not according to diameters, but superficial measure, so that a lens which magnifies ten diameters is set down as one which magnifies a hundred times, and one of two hundred and fifty diameters is advertised as magnifying five thousand times.

The pocket-magnifier has this advantage over a lens fixed in a stand, that it can be turned in every direction together with the object, so that the general details of structure can always be better made out with one of these simple instruments than with the most elaborate compound microscope ever made. The higher powers are only intended for the purpose of elucidating the minute structure of smaller points, and are rarely employed until after the observer has made good use of the pocket-lens. For example, in learning the structure of an insect, say a common gnat, it should first be thoroughly examined with the lowest power of the simple lens, and afterwards by each of the higher powers in succession, until the observer has obtained a good general idea of the form and position of the various organs, together with hints as to the portions which are best adapted for the larger instruments. After learning all those details, the observer next removes a small portion of the insect, say a wing, or a leg, and submits it to the lowest power of his compound microscope, adding successively the higher powers until he has gone over the whole of the object. By setting to work at a single subject, of whatever nature it may be, and examining it first in general and afterwards by detail, the observer will find that he has gained more than he would have learned by volumes of reading alone.

I know of no pursuit more fascinating than this, or more calculated to make him who pursues it forgetful of time, place, hunger, and cold. There is something so entrancing in the manner in which Nature gives up her wondrous secrets, that the mind seems to be entirely taken out of the world, the hours fly past as in a dream, and the day becomes too short for the pleasant labour.

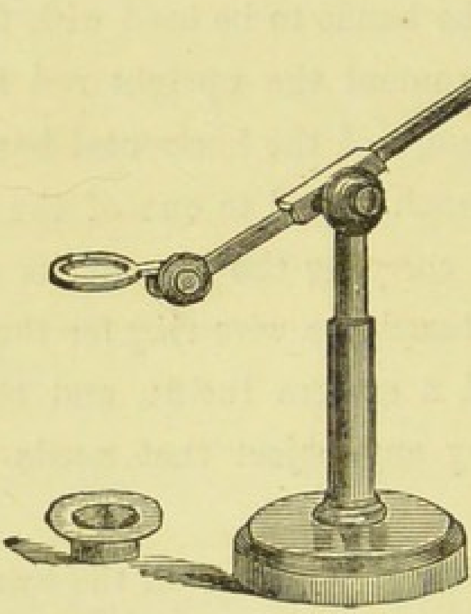


STAND FOR DISSECTING MICROSCOPE.

The simple lens already mentioned can be employed in various ways, and by a little ingenuity can be made serviceable either as a pocket-magnifier or a dissecting microscope. The latter object is thus accomplished, requiring a very trifling exercise of patience or cunning of hand. Get an iron or brass rod fixed into an iron or leaden foot, as seen in the engraving. Then bore a hole longitudinally through a rather large wine-cork, so as to slide rather stiffly over the upright rod. Then take a stout brass wire, twist one end of it into a spiral, inclosing the cork in the centre, cut it off to the required length, turn up the end of it at right angles, and slightly sharpen the point. The turned-up end may then be passed through a hole drilled in the handle of the pocket-magnifier, and the microscope is complete. The sliding cork will permit the lens to be raised to a higher or lower level, while the length of horizontal wire will permit the hands to be used with freedom.

In my own instrument the upright rod is simply a common retort-stand, and the horizontal bar is a piece of hollow elder branch lashed to one of the wire rings of the stand, and carrying the lens at its extremity. Moreover, by substituting a wire ring for the upturned point, it will hold a camera lucida, and this is very useful in sketching any object that needs rapid but accurate drawing.

For those who do not possess even the small amount of mechanical skill which is required for the construction of so simple an instrument as that which has just been mentioned, Ross's dissecting microscope is one of the best. As may be seen, it is capable of motion in every direction, and permits the lenses of different powers to be fitted or secured without any screwing or waste of time. This is often a considerable advantage when much time is given to microscopic dissection. The very best dissecting microscope that I have seen was one that was employed by Dr. Acland at the Anatomical Museum at Oxford, and was formed something on the same principle as that mentioned above. The horizontal bar was so made as to be raised or lowered by turning a screw, while it was so affixed to the upright bar, that it could be pushed aside in

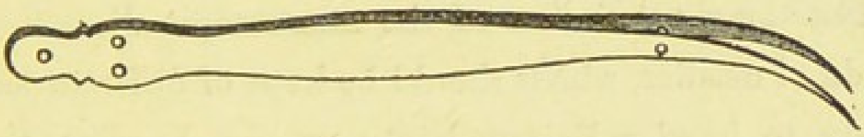


ROSS'S DISSECTING MICROSCOPE.

order to examine the dissection with the naked eye, and again drawn into its place without disturbing the stand.

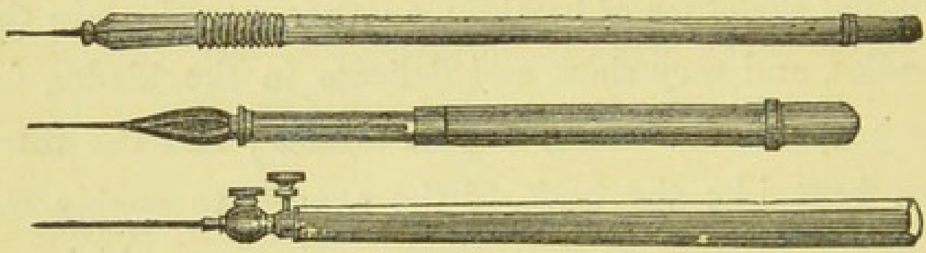
The only practical objection to these forms of the dissecting microscope is, that they do not permit the object to be seen by means of light thrown from below, but this defect is easily remedied by cutting a hole in the dissecting table and placing a mirror beneath.

The tools employed for dissection need not be many nor complicated, and can all be purchased for a very few shillings. A very small scalpel, with a double edge, is always useful, and should be extremely flat and thin in the blade, as well as kept to the very acme of sharpness by an occasional touch of a hone and razor-strap. Three pairs of scissors are needful: one tolerably stout, for cutting hard substances, such as the wing-cases and external skeletons of beetles; another, very long in the handles, and very short and delicate in the blades, for the purpose of severing minute tissues; and the third pair bent like the beak of the avocet, to enable the dissector to snip off those little projections which are



continually getting in the way, and which cannot be reached by a straight blade without running the risk of damaging the dissection.

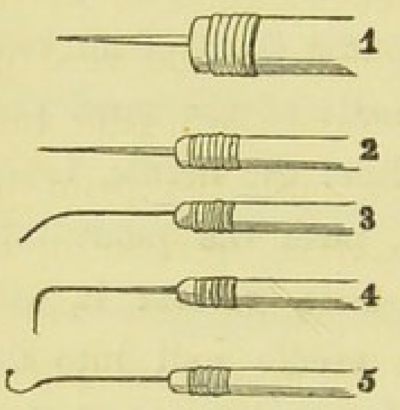
Two pairs of forceps will also be required, one straight and strong, and the other fine and curved, as seen in the engraving. In order to insure the accurate meeting of the points—a matter of very great importance—the blades play upon a pin which may be seen inserted near the curved extremity of the instrument. These forceps are generally made of brass, and are most useful. I generally carry a pair in my pocket whenever I go into the fields, for they serve to draw little insects out of their hiding places, to pick up objects too minute for the fingers, and to hold them while undergoing examination with the pocket-magnifier.



But the sheet anchor of the microscopic dissector is made of needles, which should be kept of different sizes ready to hand. Fastened into wooden handles, they are employed in "teasing" out delicate structures, so as to separate the tissues of which they are composed without tearing or cutting them. Some persons recommend that a lady's crochet-case be used, which not only contains a store of needles, but admits of changing the point whenever needed. There are also other forms of dissecting needles manufactured, three of which are represented in the illustration.

For my own part, I always find that the ivory or metal handle is too heavy, and invariably employ common camel's hair brush handles, in which the needles can be readily fastened. Five forms are all that are really useful, and many of them can be made in a few minutes. In order to fix the needles firmly in their handles, the following plan is the best. Get a convenient handle, and wrap about a third of an inch with waxed thread, leaving a little of the wood projecting without any thread. Take the needle, break it off to a convenient length, push the point into the handle so as to make a hole, reverse it, and with a pair of pliers drive the needle well into the handle, the thread preventing the wood from splitting. Now trim the wood to a point, so as to make it all look neat, and a light handy instrument is at once made.

The five forms are employed for different purposes. The first, No. 1, is a short thick needle, set in a large handle, and used for boring holes in wood, mica, cork, or wax, as may be required. It is also useful for making the holes in new handles. No. 2 is a rather fine, straight needle, and is the most generally useful of the set. Several of these should be made of different degrees of fineness. No. 3 is a slightly bent needle, valuable in getting at tissues that lie hidden under other substances. Several of these should be made, bent at different curvatures, and of different strength. No. 4 is occasionally useful for pulling thready tissues aside in order to permit another instrument to be used; and No. 5 is required for lifting a delicate structure without injuring it. The reader will observe that it has no point, but that its extremity is defended by a little knob. I may also mention that it will be an improvement if the fine scissors have also one blade terminated by a little knob.



There is no need for making a great supply of these instruments before commencing work. I always used to fit up several of 2 and 3, and to make the others as they are required. I can strongly recommend these simple little instruments, as they are very light, and are little liable to injury.

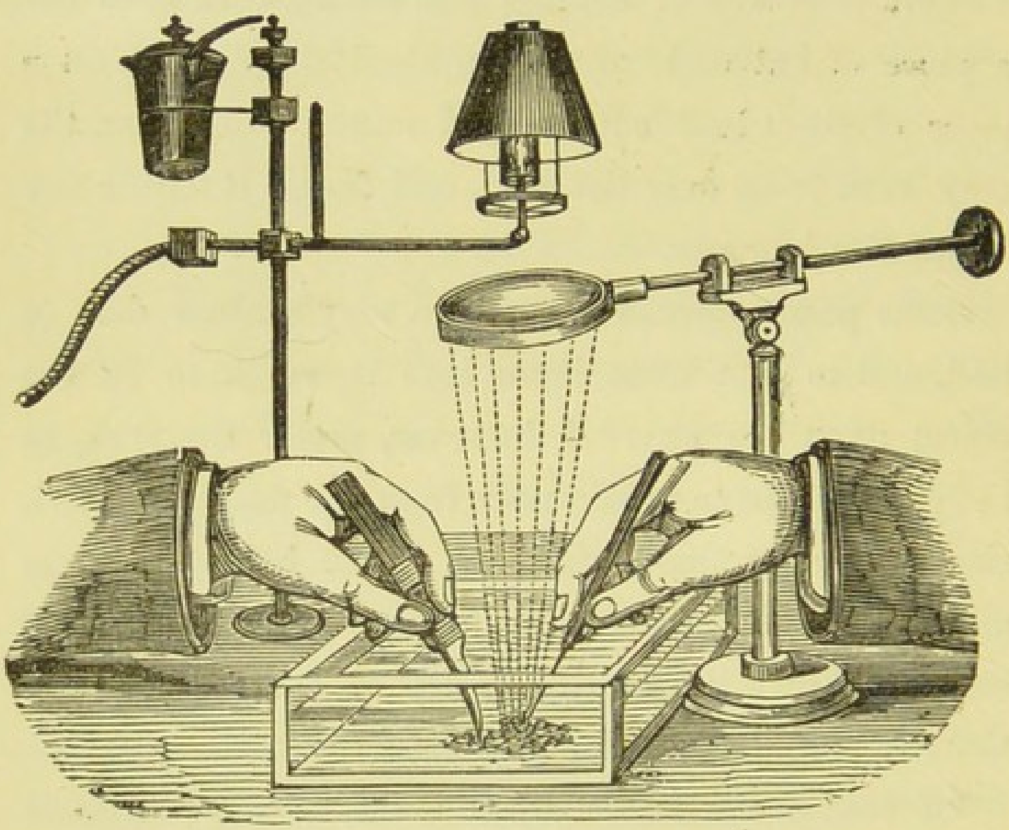
The other appliances for insect dissection are equally simple.

As all delicate structures are dissected under fluid, a shallow glass dish is required. My own are simple flat round glass cells, about one inch in depth and four in diameter. For very large objects, a dish of corresponding length is of course required. This is plentifully filled with water or spirit—generally a mixture of the two—and the dissection is sunk to the bottom by being fastened to a flat cork attached to a strip of sheet lead. The simplest way of making this loaded cork is to cut a piece of flat cork to the required size, lay it on a piece of sheet lead, cut the lead rather wider than the cork, turn it up over the edge, and fasten it with a few blows of a hammer.

Some persons prefer to make a very shallow dish of lead, and to pour melted wax into it, so as to fix the object upon the wax. I, however, prefer the cork, as the pins are apt to break away from the wax. The cork should be very fine-grained, as if the holes are large and deep, the pin is sure to plunge through the dissection, carrying with it the tip of the forceps, and thereby doing irremediable damage.

Of course the whole affair must be set in a good light, or the dissection will be impracticable. Daylight is by far the best, for I always find that by artificial light the shadows are thrown so perplexingly that it is almost impossible to make out the real structure of a delicate object, and an important tissue may be broken under the impression that it is but a shadow. If, however, artificial light must be used, the accompanying illustration will show the manner of arranging it.

The light is thrown perpendicularly upon the object by means of a common "condenser," and the hands



DISSECTING UNDER WATER.

are so placed as to avoid getting in the way of the light. In practice it will be found very useful to support the hands by means of a book or piece of wood on each side of the glass cell, as the handling becomes very awkward and fatiguing without some such precaution. The best support is made of a thick piece of board of the same height as the edge of the glass cell, flat for two inches or so, and then sloped away so as to form an inclined plane.

Great care must be taken with the points of the needles that they are perfectly smooth and polished, as if there is the least roughness they will hitch in the more delicate structures and tear them woefully. Also, the needles should not be too long, as the elasticity of the steel is apt to make them spring when pressed. The length given in the engraving is amply sufficient. The bending of the needles is easily accomplished by holding them in a candle until red-hot, when they can readily be bent into any form that is desired. By this mode of treatment they become soft and yielding, but can be immediately restored to their original hardness by reheating, and then plunging them into cold water. A spirit lamp will serve better than a candle, as it does not blacken the needle, and permits the dissector to work more freely.

A large supply of variously sized pins should be at hand, some of tolerable size, a great many minikins, and a box of fine entomological pins. I always have a loaded cork close to the dissecting cell, the cork being filled with pins of different sizes, graduated according tc their position, so that they can be taken at any moment without search or disturbance. These are employed for fastening the object to the loaded cork in the cell, and also for keeping aside the various structures as they are dissected out. The number of pins that is required is really remarkable, for in the ordinary dissection of an insect some fourteen or fifteen pins will gradually be used.

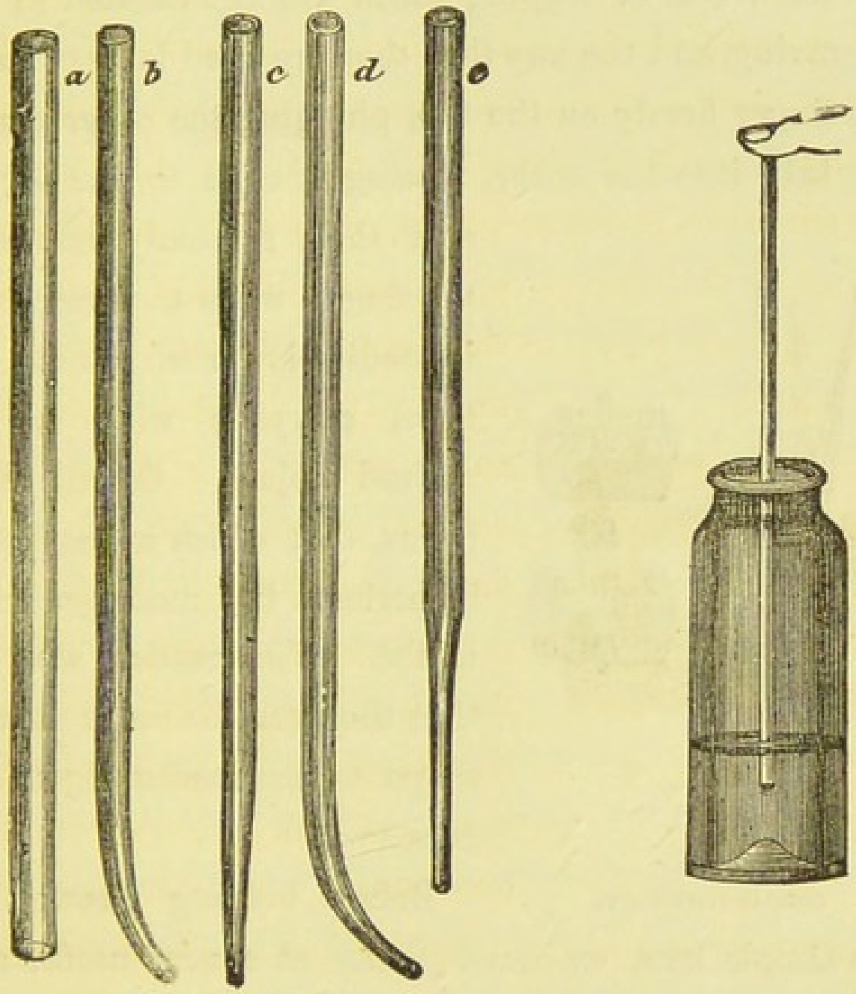
A very fine-nosed syringe is a most useful article, but its place can be very well supplied by glass tubes made after the following fashion.

Get a glass tube or two from the chemist—the diameter is of little consequence, provided that the glass be of soft quality—light the spirit lamp, and hold one of these tubes by the ends, keeping the centre over the flame and turning it continually to prevent the glass from cracking. Lower it gradually into the flame, until it becomes of a bright red heat and quite soft. Then draw the two ends rapidly asunder, and there will be two tubes, each ending in a point of very thin glass.

Break away the extremity of the point, and you will have a tube with a very fine outlet. Of course if you want a large diameter, you have only to break away the glass a little higher.

The broken end should then be held for a moment in the margin of the flame so as to round its sharp edges.

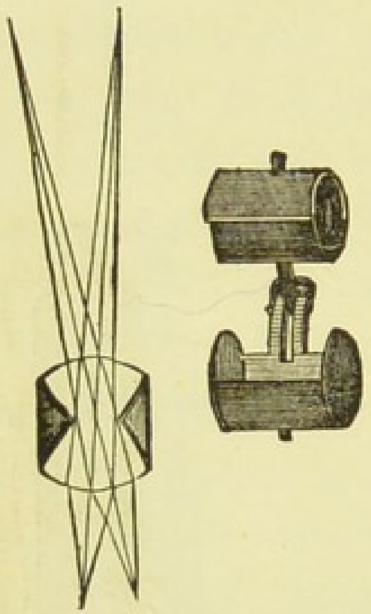
These tubes are extremely useful, being employed when very fine for washing aside any tissue that is too



DIPPING TUBES AND MODE OF USING.

delicate to be handled with the steel, and are used by putting the large end into the mouth, drawing the liquid into them by suction, and expelling it by the breath.

These and similar tubes are also useful for "dipping" out minute organisms from the water in which they live, and are therefore termed "dipping tubes." Several forms of dipping tubes are represented in the engraving, and the way that they are used is by pressing the finger firmly on the top, plunging the other end of the tube into the water, placing it close to the object, and then suddenly removing the finger, when the water will immediately rush into the tube, carrying with it the desired object. Of all these forms, that which is marked *d* is perhaps the most generally useful. The reader will see that they can be made of any shape or size, according to the occasion.



CODDINGTON LENS.

Before bidding farewell to the simple lens, we must glance at a very useful and portable form, which can be carried in the waistcoat pocket, and is quite as powerful and welldefining a magnifier as many compound microscopes. It is termed the "Coddington" Lens, and is nothing more than a polished sphere of glass, with a deep groove cut round its circumference and the hollow filled with black cement. In the illustration one of these useful little instruments is depicted, together with a section of the same, showing the manner in which the rays of light are forced to pass through the lens under similar circumstances. The "field" of this little microscope is very flat, and the definition is good in whatever way it may be held.

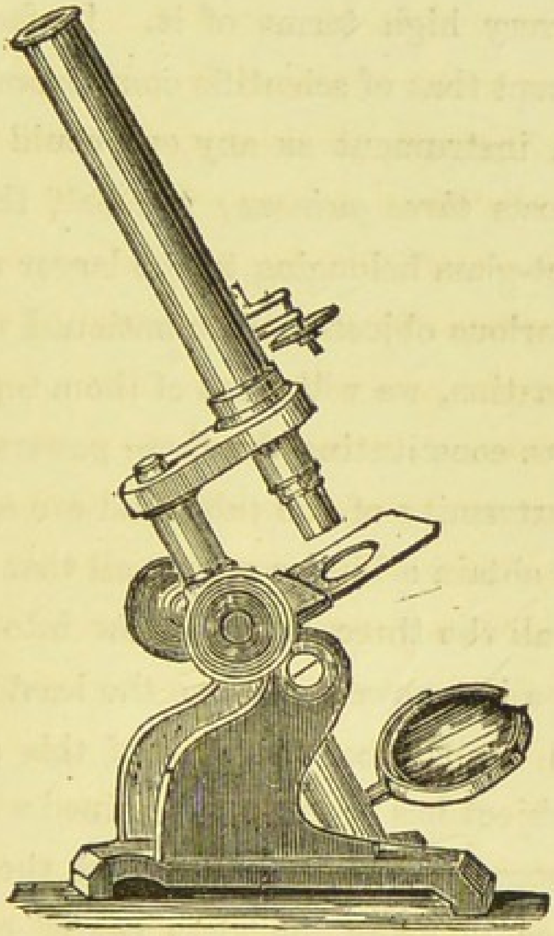
For the sake of convenient holding, the handle should be three or four times as long as that of the figure; and after a little practice the observer will set great value on this lens. There is another lens which bears some external resemblance to the Coddington, and is called by the name of the "Stanhope" lens, against which the reader is hereby warned. Dealers often try to induce their chance customers to purchase the Stanhope lens, and the reader may distinguish between them by the fact that both ends of the Coddington lens are alike; whereas in the Stanhope, one has twice the convexity of the other. The Coddington is extremely useful for a cursory examination of any object that may be found in the field, as its great power will enable the observer to make out the details of any minute structure, and to decide whether the object will be worth bringing home and placing under the compound microscope.

HAVING thus given some little attention to the simple microscope, we will pass to the more complicated apparatus termed the COMPOUND MICROSCOPE.

This invaluable instrument is made in various ways, the chief essential being that one glass is placed close to the object, and the other near the eye. In former days, the tube that contained these glasses was several feet in length, so that the whole affair might easily be mistaken for a great astronomical telescope. Into the details of structure I do not intend to enter, nor to describe the varieties of compound microscopes that are constantly produced by different makers, as the whole of the work would be absorbed in that one department alone. The accuracy with which these instruments are made is almost fabulous, and the number and beauty of their accessories is so great, that the first-rate compound microscope is said to be the only instrument in the world where the performance equals the theory on which it is made.

Such an instrument is beyond the reach of most persons, costing from forty or fifty pounds and upwards, and is therefore quite unsuited to the purposes of the present work. There is, however, a compound microscope which is a really admirable instrument, giving a flat though small field, great magnifying powers, clear definition, and is quite achromatic, *i.e.* without those fringes of rainbow colouring which are always seen surrounding the objects in inferior microscopes.

It is furnished with three powers, named the inch, half-inch, and quarter-inch object-glasses, has a sliding stage for the purpose of conveniently moving the object



EDUCATIONAL MICROSCOPE.

turns on two pivots so as to suit the position of the head, the "body" or tube where the glasses are se. is moved to and from the object by large and fine screws, called technically the "quick and slow motion," and is also supplied with dissecting forceps, a stage forceps, and a "live-box," all fitting into a neat mahogany box, so managed that supplementary appurtenances can be packed when obtained. I have subjected this instrument to careful testing, and can report in very high terms of it. In fact, for every purpose except that of scientific controversy, it is quite as good an instrument as any one could wish to see, and only costs *three guineas;* not half the price of a single object-glass belonging to the larger microscopes.

As the various objects here mentioned require some little explanation, we will treat of them separately.

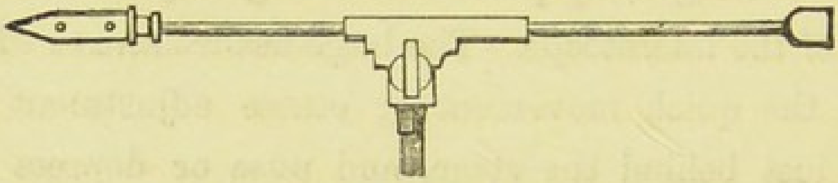
The lenses constituting the three powers screw on to the lower extremity of the tube, and are so made that, in order to obtain a higher power, all that is needed is to employ all the three, which screw into each other; two giving a less power, and one the least of all. The reader will see the convenience of this arrangement. When an object has been well examined with the lowest power, a second can be added, and the large screw turned so as to bring the glass nearer to the object, which is sure of being in the exact field of the glass. This is of no small consequence, as the hunting for a little object on a large slide under a high power is one of the most provoking of chases, and often forces the observer to remove the high power, replace it by a lower, find the object, get it in the centre of the field, change the glass again, and then bring it down upon the object. The highest power should always be nearest the object.

On the stage, *i.e.* the flat plate of metal immediately under the object-glass, may be seen the raised ledge against which the glass slide holding the object is laid, and which, by sliding up and down the stage, carries the object with it. This movement is necessary, in order to bring every portion of a large object into the field of the microscope. The large-headed screws which form the quick movement or coarse adjustment are seen just behind the stage, and raise or depress the tube by means of a rack and pinion movement. The screw of the fine adjustment is seen just above the horizontal rim, into which the body is fixed, and acts by means of a screw working against a spring.

The mirror, which may be seen below the stage, is so fitted that it can be turned in any direction, so as to throw the rays of light straight or obliquely through the object, either method being equally useful under different circumstances. The heavy stand is made of iron, and affords a firm and solid support to the instrument, a matter of no trifling consequence when the reader reflects that motion is magnified as well as substance, so that if the instrument trembles in the least degree, the object becomes almost invisible, seeming to flutter before the eyes of the observer like the whirring wings of a hovering fly.

All these portions of the instrument are affixed to the stand, but there are other parts of the apparatus which are furnished and used separately.

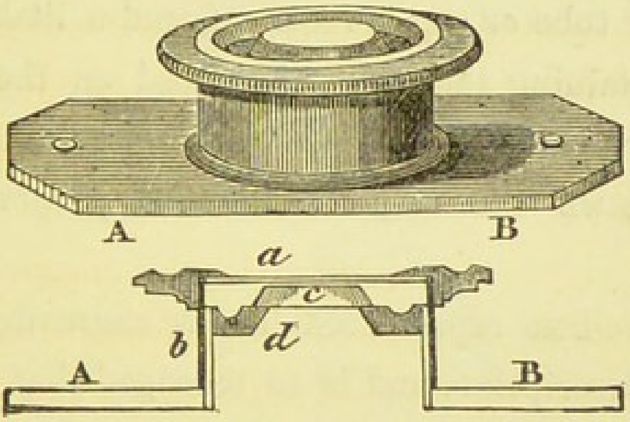
The dissecting forceps have already been described and figured on page 12, so that no further mention is needful. The stage forceps are of a very different



STAGE FORCEPS.

appearance, as may be seen by the accompanying illustration.

The dark-coloured pin at the bottom fits into a hole in one corner of the stage, in which it can be turned freely. A brass socket is hinged to the pin, and bears a steel bar, which passes horizontally through it, and carries at one end the forceps, and at the other end is either sharply pointed, or fitted with a brass cap, into which a piece of cork is firmly pressed. The reader will see that this instrument is capable of being turned in every direction, and as the horizontal bar revolves freely in the socket, any object held in the forceps can be turned round so as to afford a view of every side. To hold the object, one of the pins in the forceps blades is pressed, which separates one blade from the other, and when the pressure is removed, the elasticity of the blades, which are made of steel, brings the points together, and holds the object firmly between them.



VARLEY'S ANIMALCULE CAGE, OR LIVE-BOX.

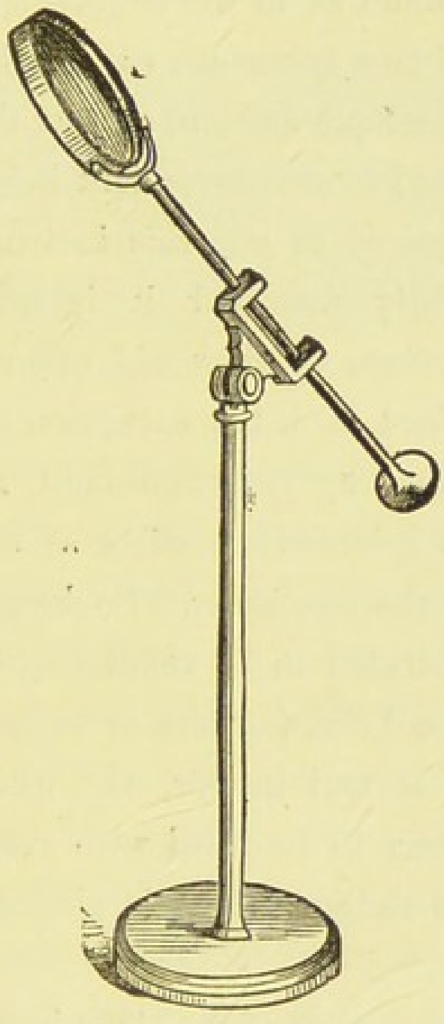
Under a low power the stage forceps are almost indispensable, but for the higher can hardly be employed at all, as the light and the focussing are both so difficult of management that the comparatively coarse forceps cannot be successfully used except by a very practised hand.

The Live-Box or Animalcule cage is also a most useful, and in fact a necessary part of the apparatus. In the illustration it is shown, together with a section exhibiting the details of its structure.

It consists of two brass tubes, sliding in each other, and each being furnished at the top with a plate of glass, so arranged that when the upper tube is pressed down to the fullest extent, the glass plates are all but in contact with each other. This instrument is used for examining animalcules, microscopic plants, and other substances, and is very simple in its operation The upper tube or cap is removed, and a little drop of water containing the object is placed on the glass of the lower tube. The cap is then replaced, and as it is pressed down the drop of water is proportionately flattened.

The live-box represented in the engraving is of a superior description, and is so managed that the glass of the lower tube is thick, and has a groove running round it like the moat surrounding an old castle. The reason of this arrangement is, that the superabundant fluid only runs over the glass into the groove, while the objects remain in their places. A B is the flat brass plate on which the lower tube is fastened, *d* is the brass-grooved ledge of the tube, *c* is the thick glass top of that tube, and *a* is the glass cover of the cap, whose sides are represented by the black perpendicular lines outside the tube.

This kind of cage is especially valuable, as the cap can be fitted with glasses of different strength, so that it can either be employed in the investigation of microscopic animalcules or in flattening sundry substances which need pressure to bring out their details. There is another instrument made for this purpose,

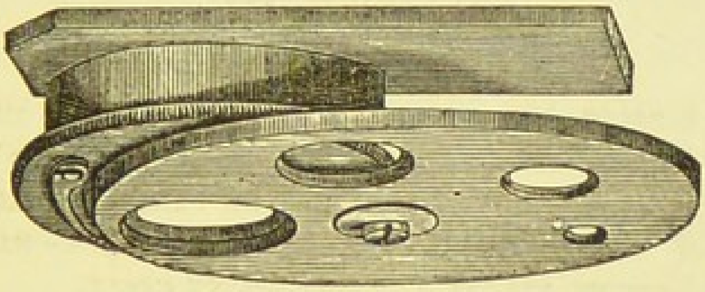


CONDENSER.

termed a "compressorium," but in careful and steady hands the live-box will answer nearly as well.

A "condenser" is generally supplied with the microscope, and, as its name imports, is used for condensing the light upon an opaque object. It is mounted in various ways, sometimes fitting into a socket on the stage like the stage forceps, but generally on a separate stand as in the engraving. The upright rod consists of two tubes one within the other, which draw out in telescopic fashion, so that the "bull's-eye" lens can be raised to any convenient height. Some little practice is required to use this instrument properly, but when rightly managed it is quite invaluable, bringing out effects which would otherwise be totally invisible. Indeed, with the exception of those objects which are viewed by polarized light, there are none which have so splendid an effect as those which are illuminated by the condenser. So large an amount of light is concentrated in so small a space that when it is refracted from hairs, feathers, or scales, especially the wing-scales of several insects, the whole field of the microscope seems to be filled with resplendent gems, flashing with a radiance that is almost painful in its intensity.

To the under surface of the stage is generally affixed a circular plate of metal, pierced with holes of various diameters, and called a "diaphragm." It is a useful instrument, and is employed for modifying the amount of light which is thrown by the mirror through the hole in the stage. By turning this plate the holes can be successively brought under the hole in the stage, and their centres are made to coincide with the centre of the object-glass by a little spring catch which is



THE DIAPHRAGM.

seen on the left hand of the engraving, and which fits slightly into a notch. As a general rule, the smaller holes should be used with the higher powers, as the "pencil" of light ought to be rather smaller than the diameter of the object-glass. Should the observer wish to shut off all the light, he has only to turn the diaphragm beyond the smallest hole, when the blank portion of the metal will pass over the hole in the stage and effectually answer that purpose.

This little preliminary dissertation is rather uninteresting, but is needful in order to enable the reader to comprehend that which is to follow.

CHAPTER III.

VEGETABLE CELLS AND THEIR STRUCTURE—STELLATE TISSUES—SECONDARY DEPOSIT—DUCTS AND VESSELS—WOOD-CELLS—STOMATA, OR MOUTHS OF PLANTS—THE CAMERA LUCIDA, AND MODE OF USING—SPIRAL AND RINGED VESSELS—HAIRS OF PLANTS—RESINS, SCENTS, AND OILS—BARK CELLS.

We will now suppose the young observer to have obtained a microscope, and learned the use of its various parts, and will proceed to work with it. As with one or two exceptions, which are only given for the purpose of further illustrating some curious structure, the whole of the objects figured in this work can be obtained without any difficulty, the best plan will be for the reader to procure the plants, insects, &c. from which the objects are taken, and follow the book with the microscope at hand. It is by far the best mode of obtaining a systematic knowledge of the matter, as the quantity of objects which can be placed under a microscope is so vast, that without some guide the tyro flounders hopelessly in the sea of unknown mysteries, and often becomes so bewildered that he gives up the study in despair of ever gaining any true knowledge of it. I would therefore recommend the reader to work out the subjects which are here mentioned, and then to launch out for himself in the voyage of discoveries. I speak from experience, having myself known the difficulties under which a young and inexperienced observer has to labour in so wide a field, without any guide to help him to set about his work in a systematic manner.

The objects that can be easiest 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 exhaustless supply of microscopic employment. Even the humble vegetables that make their daily appearance on the dinner-table are highly interesting; and in a crumb of potato, a morsel of greens, 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 1, fig. 1, may be seen three cells of a somewhat globular form, taken from the common strawberry. Any one wishing to examine these cells for himself may readily do so by cutting a very thin slice from the fruit, putting it on a slide, covering it with a piece of thin glass, which may be cheaply bought at the optician's, together with the glass slides on which the objects are laid, and placing it under a power of two hundred diameters. 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, 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 farther.

The cell is a closed sac or bag formed of a substance called from its function "cellulose," and containing certain fluid contents as long as it retains its life. In the interior of the cell may generally be found a little dark spot, termed the "núcleus," and which may be seen in fig. 1, to which we have already referred. The object of the nucleus is rather a bone of contention among the learned, but the best authorities on this subject consider it to be the vital centre of the cells, to and from which tends the circulation of the contained fluid. In point of fact, the nucleus may be considered as the heart and brain of the cell. On looking a little closer at the nucleus, we shall find it marked with several small light spots, which are termed "nucléöli."

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 very variable in size, number, and arrangement.

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, when it was found that the blue tint spread over the pits together with the cell-walls, showing that the membrane is continuous over the pits.

Fig. 7 exhibits another form of cell, taken from the Spargánium, or bur-reed. These cells are tolerably equal in size, and have assumed a squared 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 squared facets of the compound eyes belonging to 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 strongly the beautiful manner in which the various arms of the stars meet each other. A smaller group of stellated cells may be seen in fig. 4, taken from the stem of a large Rush, and exemplifying the peculiarities of the structure.

The reader 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 endued 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 knife, and laid under the field of the microscope.

Looking towards 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 in their elongated state, 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. Many experiments on this subject were made by the Rev. Lord S. G. Osborne, and may be seen at full length in the pages of the *Microscopical Journal*, the subject being too large to receive proper treatment in the very limited space which can here be given to it.

One very remarkable point is, that the carmine was always found to be taken most plentifully into the nucleoli, and to give them a very deep colouring. These specimens exhibited the phenomenon which has already been casually mentioned, that the rotation of the granules in the interior of the cell takes place to and from the nuclei.

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 portions, so that each portion takes the shape which is 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, p. 29.

This secondary deposit—I pray the reader's pardon for using such language, but there is no alternative—is exhibited in more modes than one. 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 gives another good instance of a 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 congeries of cells, containing their nuclei, starting originally end to end, but swelling and dividing at 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. No one who did not know the history of that little group could imagine what would be its perfected condition, for it might either spread itself into a leaf, or extend itself into a flower, or end its days as a hair, for all the indications that it affords of its future.

Having now examined the principal forms of cells, we arrive at the "ducts," 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. At first the young microscopist is apt to puzzle himself between ducts and vessels, but may easily set himself right by remembering that ducts are squared at their ends, and vessels or wood-cells are pointed.

In fig. 19 the reader will find a curious example of the "dotted duct," so called from the multitude of little markings that cover its walls, and which 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 very 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 duct (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 duct.

Fig. 23 exhibits a duct 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 duct. For this reason it is termed a "netted duct." A very curious instance of these structures is given in fig. 26, at the bottom of the plate, where are represented two small ducts from the wood of the Elm. One of them—that on the left hand—is wholly marked with spiral deposit, the spires 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 the common Radish, which is very prolific in these interesting portions of vegetable nature.

There is another remarkable form in which this secondary deposit is sometimes arranged, that is well worthy our notice. An example of this structure is given in fig. 18, taken from the stalk of the common Fern or Brake. 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 "scalariform," or ladder-like form.

In the wood of the Yew, to which allusion has already been made, there is a very peculiar structure, found only in those trees that bear cones, and therefore termed the coniferous glandular 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 all the peculiar formation which has just been mentioned, and in addition exhibits the situation of the oil-cells which give to the wood its well-known fragrance.

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.

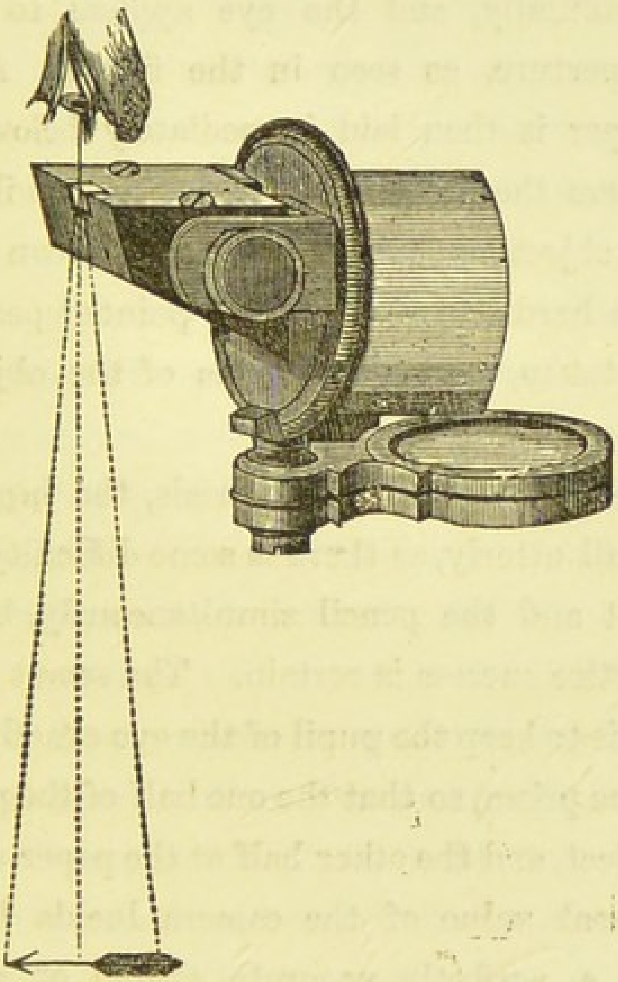
The pointed, elongated shape of the wood-cells, is very well shown in the common Elder-tree (see fig. 15). In this instance the cells are without markings, but in general they are dotted like fig. 21, an example cut from the woody part of the Chrysanthemum stalk. This affords a very good instance of the wood-cell, as its length is considerable, and both ends 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" described on page 29, or by the intervals between the spiral deposit.

At the right-hand bottom corner of Plate I. (fig. 20), 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 "stómata" as they are scientifically called, scientific people always liking to use a long Greek word where a short English one would do as well.

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. Their edges are protected by certain "pore-cells," or "guard-cells," so called from their function, which, by their change of form, cause the mouth to open or shut, as is best for 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 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, &c., so as to note the different sizes and shapes of the stomata.

Let me here notice that the young microscopist should always sketch every object which he views, as



CAMERA LUCIDA.

he will thus obtain a far clearer and more lasting impression of the subject than can be gained merely by examining one object after another. By far the best mode of sketching is to use the Camera Lucida, a figure of which is given on the preceding page.

It consists of a prism of glass, affixed to a brass tube, which is slid upon the eye-piece of the microscope, after removing the perforated cap. The microscope is then laid horizontally, and the eye applied to the little oblong aperture, as seen in the figure. A piece of white paper is then laid immediately below the eye-piece, where the large arrow is seen in the illustration, and the object will apparently be thrown upon the paper. A hard and very sharply pointed pencil should then be taken, and the outline of the object traced upon the paper.

On the first two or three trials, the beginner will perhaps fail utterly, as there is some difficulty in seeing the object and the pencil simultaneously, but with a little practice success is certain. The secret of this instrument is to keep the pupil of the eye exactly upon the edge of the prism, so that the one half of the pupil looks at the object, and the other half at the paper and pencil.

The great value of the camera lucida lies in the fact that a perfectly accurate sketch of any object can be taken by one who knows nothing whatever of drawing, the process being much the same as that of drawing on a transparent slate. The saving of time is very great, as a sketch can be made with a rapidity that seems almost marvellous to a bystander, and the drawing is sure to be in perfect proportion. The reader will see by the diagram of the rays that the size of the drawing will be precisely according to the distance of the camera from the paper, so that if he wishes to make a small sketch, he places the paper close to the prism, and if he desires a large drawing, removes it to some distance. Indeed, a very large diagram, suitable for the walls of a lecture-room, can be made by laying the paper on the floor, and drawing with a pencil fixed in a very long handle. Minute details of colour, &c. are added after the outline sketch is completed.

There are several modes of attaining the same end, among which the steel mirror and the neutral glass are the best. The former is a very tiny circular plate of steel, placed in the same position as the edge of the camera lucida, and turned at such an angle that the eye looks *in* the mirror at the object, and *around* it at the paper. The cheapest instrument for this purpose is the neutral glass plate, invented by Dr. L. Beale, and which will be found to perform admirably the functions of the camera lucida, without costing more than one-fourth of the price.

By means of a little ingenuity, the camera can be mounted on the stand of the dissecting microscope, and can be thus employed for sketching solid objects or copying drawings. By a neat adjustment of the height of the instrument the camera lucida will always produce a sketch exactly to scale, and will give a drawing of twenty, thirty, or a hundred diameters at will. It will therefore be seen that the draughtsman must be very careful to have the instrument placed at an established series of heights above the paper, and he should always append to each sketch the magnifying power with which it was drawn. Thus—

"Epidermis and stomata of Holly-berry, $\frac{4}{10}$ × 150."

By which formula will be understood that the object glass employed is that called the "four-tenths" glass, and that the object is magnified one hundred and fifty diameters. Unless this precaution be taken, great confusion in respect to the size of the object is sure to arise.

To return to our former subject.

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 observing 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, or "epidermis," as it is scientifically termed. 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. The closure or expanding of the mouth depends most on the state of the weather, and, as a general rule, they are open by day and closed at night. Some plants are provided with four guarding cells, which are arranged in different manners.

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 cuticle 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.) The peculiar elongated cells will not be seen equally spread over the whole surface of the leaf, as they are hidden by a congeries of shorter and thicker cells, covered with chlorophyll which conceals their shape. There are, however, a number of longitudinal bands running along the leaf, where these cells and mouths appear, without anything to veil their beauty. The stomata 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, while a group of three or four are often seen clustered closely together.

Fig. 3 on the same plate exhibits a specimen of 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, being 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 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 them unrolls itself in proportion to the force employed. In many cases these coils 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 nature must be greatly struck with the analogies between different portions of the visible creation. These spiral structures which we have just examined are almost identical in appearance, and entirely so in functions, with the threads that are coiled within the breathing tubes of insects. Their object in both cases is twofold, namely to give strength and elasticity to a delicate membrane, and to preserve the tube in its proper form despite the flexure to which it may be subjected. When we come to the anatomy of the insect in a future page, we shall see this structur further exemplified.

In some cases the deposit, instead of forming spiral coil, is arranged in a series of rings, and is then termed "annulated." A very good example of this formation is given in fig. 6, being a sketch of a ringed 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 congeries of 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.

The Hairs of plants always 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 arising 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 Heartsease, 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 recognised as a true hair.

In fig. 8 is a curious example of a hair taken from the white Arabis, one of the cruciform 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 the 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 Spiderwort, 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 edgeways 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 screw movement, and the hair brought gradually into focus from its top to its base. The general idea of this hair is not unlike that which characterises the sting of the bee or wasp. 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, which goes scientifically 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 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 garden Verbena.

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. 30 exhibits another hair from the same locality, on which the spikes are differently arranged, and fig. 29 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 ere this, 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. Other examples are given on the same Plate.

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 ouble 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 in 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 exceedingly hardened by secondary deposit, and the hairs are then better known by the name of spines. Two examples of these strengthened hairs are seen in figs. 37 and 38, the former 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. The latter hair is taken from the Opuntia.

The mode in which hairs increase in length is well shown in fig. 10, which 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.

Several hairs are 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 Lobelia. In order to exhibit these markings well, a power of two hundred diameters is needed. 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, club-like sticks in which some farmers delight, where the projections have been formed by the pressure of a honeysuckle or other climbing plant.

A hair of a similar character, but even more 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 antennæ belonging to certain 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 flowers, and may be compared with figs. 33 to 35 on Plate III.

Fig. 26 offers an example of the squared 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 Beechnut, showing a cell with its layers of secondary deposit. These are but short and meagre accounts of a very few objects, but space will not permit of further elucidation, and the purpose of this little work is not to exhaust the subjects of which it treats, but to incite the reader to investigation on his own account, and to make his task easier than if he had undertaken it unaided.

In the cuticles of the Grasses and the Mare's-tails 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. I prepared the specimen from which the drawing was 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 obsidian swords of the ancient Mexicans, or the shark's-tooth falchion of the New Zealander.

CHAPTER IV.

STARCH, ITS GROWTH AND PROPERTIES—SURFACE CELLS OF PETALS—POLLEN AND ITS FUNCTIONS—SEEDS—MOUNTING OBJECTS IN CANADA BALSAM—MOUNTING OBJECTS DRY AND IN CELLS—HOW TO MAKE CELLS—TURN-TABLE—PRESERVATIVE FLUIDS.

THE white substance so dear to the laundress under the name of Starch is found in a vast variety of plants, being distributed more widely than most of the products which are found in the interior of vegetable cells.

The starch grains are of very variable size even in the same plant, and their form is as variable as their size. Sometimes the grains are found loosely packed in the interior of the cells, and are then easily recognised 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 the iodide of potassium. 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 iodide of potassium, and in this case the iodine has the effect on the starch granules of staining them blue. They are so susceptible of this colour, that when the liquid is too strong, the grains actually become black from the amount of iodine which they imbibe.

Nothing is easier than to procure the starch granules in the highest excellence. 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 a power of a hun dred or a hundred and fifty 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 which are now floating 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 focussing 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. All the lines evidently refer to the little dark spots at the end of the granule, called technically the "hilum."

The mode by which the starch granules increase in size has long been a problem to microscopists, and seems likely to remain so for the present, one party asserting that the outermost layers are the youngest, and others that they are the oldest. All, however, are agreed upon the one point, that the delicate lines are boundaries of successive layers of the substance of which the granule is composed.

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 they 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 i being 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, their dimensions are exceedingly small, and, except to a very practised eye, they could not be recognisable as starch grains.

Fig. 3 is a good example of a starch-grain of Wheat exemplifying the change that takes place by the effects of combined heat and moisture. It has already been observed that cold water exercises little, if any, perceptible influence upon the starch; but it will be seen from the illustration, that hot water has a very powerful effect. When subjected to this treatment, the granule swells rapidly, and at last bursts, the contents escaping in a flocculent cloud, 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, and 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 a species of Canna, supposed to be *C. edúlis,* 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 the opticians.

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 so as to alter the shape and puzzle a novice. Fig. 16 is the compound granule of the Oat, which has already been mentioned, together with some of the simple granules separated from the mass; and fig. 15 is an example of the starch-grains obtained from the underground stem of the Horse-bean. It is worthy of mention that the close adhesion of the Rice starch into those masses is the cause of the peculiar grittiness which distinguishes rice flour to the touch.

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 translucent matter 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, more rightly called a wood-cell.

We will now examine a few examples of surface cells.

Fig. 5 is a portion of epidermis stripped from a Capsicum pod, exhibiting the remains of the nuclei in the centre of each cell, together with the great thickening of the wall-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. These lines were long thought to be hairs; but Mr. Tuffen

West, in an interesting and elaborate paper on the subject, has shown their true nature. From his 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 instances it is so developed as to resemble a hair. Indeed, Mr. West has concluded that these elevations are nothing more than rudimentary hairs.

The dark radiating lines are shown by the same authority to be formed by 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 bars affixed to the walls and their points tending towards the centre, and these teeth are, according to Mr. West, formed of secondary deposit.

In fig. 32 the petal of the common garden Balsam is shown, where the cells are observed to be elegantly waved on their outlines, and with plain walls. The petal of the Primrose is seen in fig. 34, and that of the yellow Snapdragon in fig. 33, in which latter instance the surface cells assume a most remarkable shape, running out into a variety of zigzag outlines that quite bewilder 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 upon 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 which represent the male sex, 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 only marked 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, and, 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 otherwise too delicate membrane, after the same principle that gives to "corrugated" iron such strength in proportion to the amount of material. Fig. 18 is the pollen of the Wall-flower, 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 or a nectary of a flower, it immediately begins to swell, and seems to "sprout" like a potato in a damp cellar, 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 process better than can be achieved by mere verbal description. The pollen-tubes then insinuate themselves among the cells of the stigmas, and continually elongating, worm their way down the "style" until they come in contact with the "ovules." By very careful dissection of a fertilizing stigma, the beautiful sight of the pollen-tubes winding along the tissues of the style may be seen under a high power of the microscope.

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 a "protoplasm," or that 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 will often be found useful to try the effect of different acids upon them.

Fig. 20 is the pollen of the common Violet, and is easily recognisable 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 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" in which it is developed. In many cases the form of the grain is clearly owing to the direction in which these cells are 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. The reader must, however, bear in mind that the whole subject is as yet rather obscure, and that further discovery may throw a different light on many theories which at present are accepted as established rules.

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 focussing to observe them properly; for the diameter of the grain is so large, that the focus must be altered to suit each individual projection. Their office is, probably, to aid in fertilizing.

The Seeds of plants are easier of examination even 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 waim into a plate of wax, and then dissect with a pair of needles, forceps, and scissors under water. 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, or Galium, 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 is the seed, or rather the fruit, of the common red Valerian, and is introduced for the purpose of showing the 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 plumy 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.

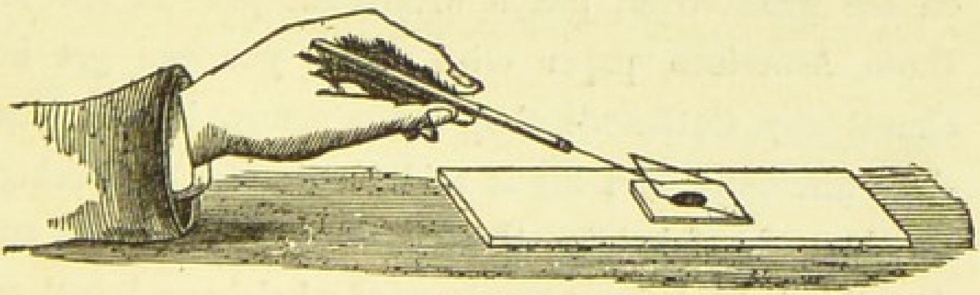
On fig. 50 is shown a seed of the Burr-reed; a structure which is remarkable for the extraordinary projection of the four outer ribs, and their powerful armature of reverted barbs. Fig. 51 shows another form of parachute seed, found in the Willow-herb, where the parachute is not expanded nearly so widely 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, 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.

Many seeds can be well examined when mounted in Canada balsam, the manner of performing which task is simple enough, and yet is often very perplexing to a beginner.

VERY little apparatus is required. A sixpenny bottle of the best balsam, a spirit-lamp, a metal-plate standing on four legs, so as to form a little table about four inches in height, some ether, spirits of turpentine, and liquor potassæ in bottles, are all the essentials, besides a supply of slides and thin glass covers. The great difficulty in mounting objects in Canada balsam is to keep them free from air-bubbles; but by proceeding in the following manner, very little difficulty will be found.

Take one of the curved dipping tubes, put some balsam into it, cork up the wide end and let it stand on its head until wanted. Lay the glass slide on the metal table, light the spirit-lamp, and place it under the table so as to warm the slide throughout, but not to overheat it. Then take the seed, put it into the spirit of turpentine, and let it wait there while the slide is being warmed.

The next process is to remove the lamp, and to hold

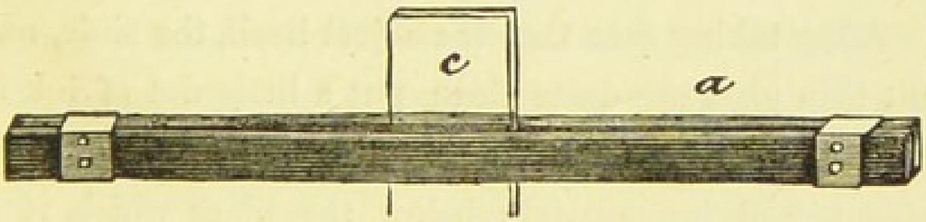


PUTTING UP AN OBJECT IN A CELL OR CANADA BALSAM.

the glass tube containing the balsam over the flame, when the balsam will immediately run towards the orifice, and a drop will ooze out. This drop should be placed on the centre of the slide, and the seed taken out of the turpentine, laid on the warm balsam, and gently pressed into it with one of the dissecting needles. With the needle turn the seed about a little, so as to make sure that no air-bubbles are clinging to its surface, and then take a piece of perfectly clean thin glass, warm it over the spirit-lamp, and lay it on the balsam in the manner here shown. Lower the glass very carefully, and slowly cover the balsam ; or when you come to press it down, the object will shoot out at the side, and all your trouble have to be taken over again. When you have laid it nicely level, press it down with the separated points of your curved forceps, and see that no bubbles have made their appearance. Having satisfied yourself about this matter, lay a small circular piece of thick pasteboard or a slice of a small cork on the glass cover, put it within the jaws of one of those American paper clips which you can get in almost any stationer's shop for a penny, let the clip close gradually, and lay it aside to harden. Another simple mode of holding the thin glass cover firmly on the slide is by tying two pieces of whalebone together as in the engraving, and placing the slide between them, a piece of cork or pasteboard being previously laid on the cover as already recommended.

During the pressing process a large amount of balsam will be squeezed around the edges of the thin glass, and may easily be removed by scraping it with the heated blade of an old knife kept for the purpose, and then rubbing the edges clean with a rag moistened with ether or spirits of turpentine.

Some structures require to be soaked for a considerable time in turpentine, and others in liquor potassæ, before they can be made sufficiently transparent to be mounted. The ether will be found very useful for cleaning the balsam from the fingers and points of the needles, and is, moreover, of great service in removing the unpleasant smell that results when turpentine is



SLIDE HOLDER.

spilt on the hands. If, in spite of all precaution, air-bubbles will make their appearance in the balsam, try to stir them to the top with one of the needles, and then break them by heating the needle and touching them with the point.

After waiting until the balsam is quite hard-set, which will not safely take place for six or eight hours, and is most certain when suffered to remain quiet for a night or two, the slide may be cleaned as directed above, and either kept as it is or covered neatly with paper, perforated on the spot where the object appears. The microscopist should be careful to label every preparation as soon as it is made, and it is best to write with ink on one end of the slide before proceeding to put up the object upon it, and to wash off the writing just before the label is affixed. A little want of such precautions will cause great confusion and loss of time, and often renders a valuable collection quite useless.

The dry mode of preparing permanent objects for the microscope is much more simple, and is managed as follows.

After taking care that the object itself, the slide, and the thin glass are quite clean, put a little dot of ink in the very centre of the slide, on the opposite side to the object, and immediately below the place which it is intended to occupy, so as to act as a guide during the process. Lay the object carefully over the ink dot, place the thin glass very lightly upon it, and fasten it down with two or more strips of thin paper pasted or gummed round its edges. Some persons prefer to fasten it with gold size; but I have always found the paper to answer quite as well, and not to be nearly so troublesome.

Now lay it aside to dry, and get ready a piece o.

small-patterned ornamental paper, with a hole punched through it just where it comes upon the object. The easiest plan is to cut a large supply of paper covers, and make the holes with a common gun-wad punch. In order to save materials and space, I frequently mount two dry objects in the same slide, one at each end, and ticket them on a rather large label pasted in the intermediate space between them. When the object is firmly fixed, take some thin coloured paper, blue or red is the best, and cover all the edges of the slide with it, pressing it very closely upon the glass, and then apply two of the ornamental paper covers, one above and the other below, so that the two holes are opposite each other, smooth them carefully down, and lay them aside. Covers, stamped and punched for the purpose, are sold at most of the opticians', but I recommend every one to depend as little as possible on his purse, and as much as possible on his fingers.

As we are speaking of the mode of preparing permanent objects for the microscope, we may as well glance at another method which is extremely useful in many cases which require much more care and time than with the dry mode or the Canada balsam. It is termed mounting in cells, and is principally employed for those objects which require to be immersed in fluid.

The cells in which the fluid is contained are made in various ways, some being hollows sunk in the glass slide, others built up like glass boxes, by the aid of cement at their edges; others being made of glass tubes cut into segments, and cemented firmly on the slide; and others, of a ring of varnish in which the fluid is contained, thus forming very shallow cells holding a mere film of fluid. The first kind of cell can easily be obtained by purchase, as the slides are made expressly by the glass manufacturers. As, however, they are not one whit more useful than the mere varnish cells, they need no further mention.

The "built-up" cells are made of slips of glass cut to the required size, and laid flat upon the slide if the cell is to be a shallow one, and set on their edges if a deep cell is required. The cements used for this purpose are various, and seem to answer according to the hand which uses them, each person preferring his own mode. Marine glue is an admirable cement, especially for deep cells, but it requires a very high temperature to get it to work freely, and the risk of scorching the fingers is rather great, as I can personally testify.

Whatever cement may be used with deep cells, it is always better to fasten narrow strips of glass over the junctions, and a triangular slip at each interior angle adds greatly to the strength of the fabric. The great fault of these deep cells is their unpleasant habit of leaking after a while, and the consequent admission of air-bubbles. As, however, they are very seldom required for the microscope, the amateur may as well purchase the few that he will want, and only make those of easy manufacture.

The tube-cells are easily made by cutting a glass tube into pieces of the required length, grinding down each surface on a level stone with water, and cementing one end to the glass slide. The tubes are easily cut by notching them with a file, and then running a hot iron round them, when they are tolerably sure to break off level. At first, they are apt to crack upwards or downwards, but a little practice soon sets matters right. Tubes fit for this purpose can be obtained at an easy rate at any glass manufacturer's, circular, oval, or squared, and almost of any needful diameter. Some very large cells made by a friend of mine were cut out of bottles, but I never could master the art of their manufacture myself, the glass always splitting in wrong direction.

The most useful cell, and that which is in general use among microscopists, is the cement cell, which is nothing more than a ring of cement drawn on the slide, which, when hard, holds the fluid. Some persons who do not care for appearances make their cells square, by drawing the figure on the glass with a pen, or laying the slide upon a square ready drawn on paper, and then painting the varnish upon it. The circular cell is, however, much neater, and can be made by substituting a circle for the square, and painting the cement neatly upon the line, taking care not to let the brush trespass within the circle.

A very neat little apparatus, invented by Mr. Shadbolt, is used for making circular cells, and can be purchased for five shillings, or constructed by a little ingenuity. It is called a turn-table, and consists merely of a horizontal revolving plate of metal, on which the slide is laid, and fastened with two clips while the table revolves. The centre of the slide must of course be brought over the centre of the table, and then, if the brush, charged with varnish or cement, is held to the slide, it immediately strikes a perfect circle, which may be made smaller or larger, according to the distance of the brush from the centre. Generally, the turn-table spins by its own weight, when propelled by the hand, but the addition of a multiplying wheel is very simple, and makes a much more convenient form of apparatus. The ring of cement must be made very wide, and nicely flattened on the upper surface.

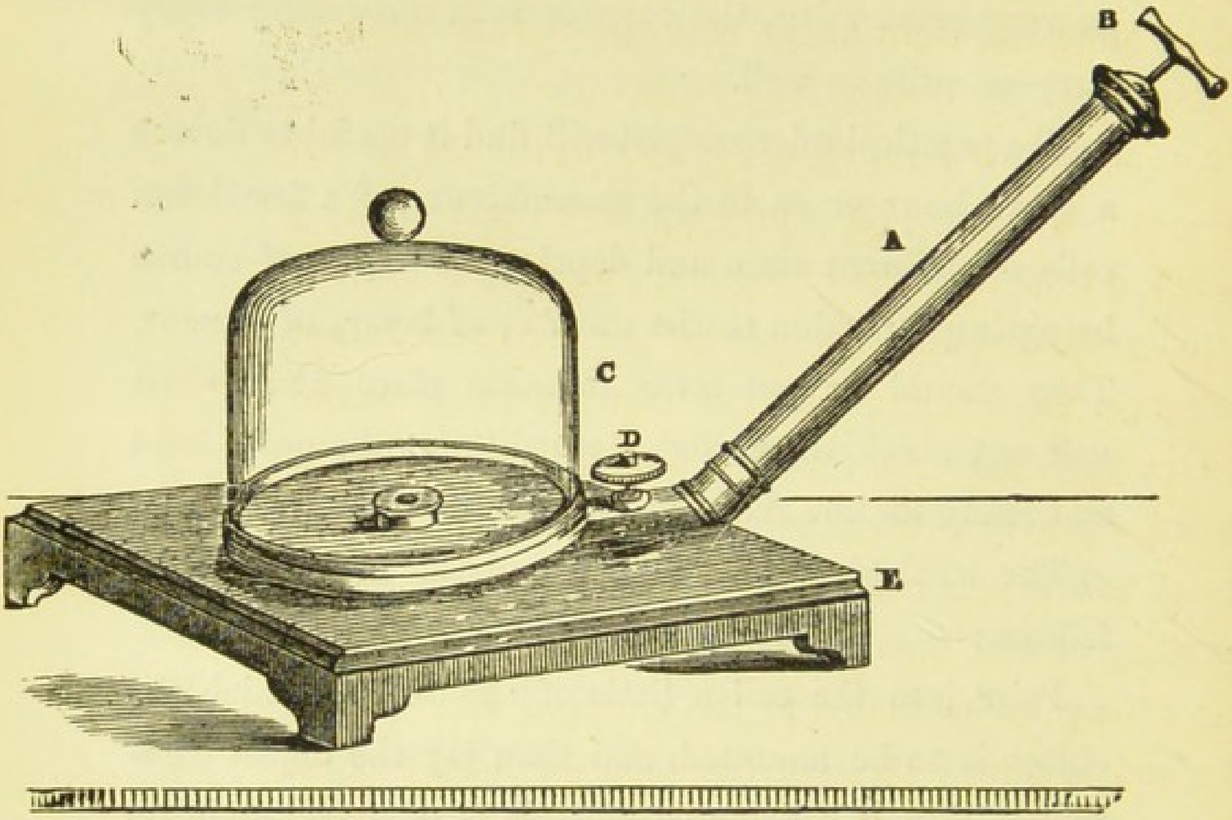
Cells of thin glass are sometimes made, but are of no very great value, the varnish cells answering every purpose quite as well.

The practical microscopist will find it useful to devote a spare hour or so to the manufacture of a few dozen cells of different sizes and depths, the depth of course being in proportion to the number of layers of cement. They should be put away in some place where dust will not reach them, and they will then be quite hard and ready for the reception of the fluid when needed.

The method of mounting an object in a cell is as follows:—

Pour into the cell a little of the fluid in which the object is to be mounted, and then lay the object carefully within it. Sometimes, if it is of a very delicate structure, the best plan is to immerse the whole slide in the fluid, float the object into the cell, and then lift it all out together. This precaution, however, is very seldom needed. Having laid the object in the cell, pour some more of the fluid upon it, and fill it up like a "bumper" of wine, letting the fluid stand well above the level of the cell. Lay it aside for a time in order to let all air-bubbles rise to the surface, and be sure to cover it with a shade, or put it in some place where the dust will not get into the cell.

A very expeditious mode of getting rid of the bubbles is to place the cell in the receiver of an air-



AIR-PUMP.

pump, when, after a very few strokes, all the bubbles will come to the surface, break, and disappear. An air-pump, such as that represented in the engraving, is made by Mr. Baker, of Holborn, for a small sum.

Having been quite satisfied that the bubbles have been expelled, take a circular thin glass cover, not quite large enough to reach to the outer edges of the ring of cement, and lay it carefully on the cell, in the manner employed in mounting an object in Canada balsam, page 87. When it lies quite level, take some blotting paper, and carefully dry up the superfluous fluid which will have run out of the cell, and which must be totally removed before the cover can be fastened down.

When the edges of the cover are perfectly dry, hold it down with the forceps with the left hand, and paint a thin layer of gold-size all round the edge of the cover, so as to fasten it to the cell. Do no more to it for at least six hours, but lay a little weight of lead—a bullet with a flattened side answers admirably—on the cover, and leave it to harden. After a sufficient lapse of time, another layer of varnish may be added, until the cover is hermetically sealed on the cell, and neither air can enter nor fluid escape. Unless the first layers of varnish be extremely thin, and very little material used, it is sure to run into the cell, and mar the beauty of the preparation: asphalte varnish is best for the few last layers. In all cases, another coat of varnish after the lapse of a few months can do no harm, and may save a really valuable object.

Sealing-wax varnish is often useful for the double purpose of cementing and giving a neat outside to preparations, and is made by breaking the best black or red sealing-wax into little pieces, pouring spirits of wine over them, and letting them dissolve. The bottle should be frequently shaken, as the sealing-wax is apt to settle at the bottom. It is very useful when time is a matter of consideration, as the spirit evaporates very quickly, and the varnish will become quite hard in a very few minutes.

The fluids employed for mounting many soft objects are very various; some of the best and most easily made are here given.

For vegetable tissues, algæ, &c.: 1. Distilled water with a little camphor. 2. Distilled water with a little corrosive sublimate. This substance is very useful in preventing the growth of fungi, which are apt to develop themselves in preparations, and totally disfigure the object therein. The microscopist can, however, take an appropriate revenge by magnifying and drawing them. 3. Distilled water 1 ounce, salt 5 grains, a very little corrosive sublimate. 4. Glycerine, either pure or dissolved in water, in various proportions. Deane's gelatine is very handy for vegetables, as they can be placed in it while wet, and only need to be laid on a warm slide, covered with a drop of gelatine, and then covered with thin glass as if they were set in Canada balsam. There are many other fluids employed by different microscopists, but these are amply sufficient for all ordinary purposes.

For animal tissues: 1. Chloride of zinc 20 grains, distilled water 1 ounce. This is one of the best substances known for this purpose. 2. Goadby's solution, No. 1. Bay-salt 4 ounces, alum 2 ounces, corrosive sublimate 2 grains, boiling distilled water 1 quart. This is the strongest and most astringent of his three solutions, and is not very often employed. 3. Goadby's solution, No. 2. Same as the preceding, except that there are 4 grains of corrosive sublimate, and the quantity of water is doubled. Various modifications of this fluid can be made, so as to suit particular objects. Spirit should be avoided in cells as much as possible, as in process of time it is tolerably sure to make its way through the cement. Canada balsam is useful both for the harder vegetable and animal substances, and has already been mentioned. For mounting many crystals, castor oil is a very good preservative, but Canada balsam answers admirably in most instances.

CHAPTER V

ALGÆ AND THEIR GROWTH — DESMIDIACEÆ, WHERE FOUND — DIATOMS, THEIR FLINTY DEPOSIT—VOLVOX—MOULD, BLIGHT, AND MILDEW—MOSSES AND FERNS — MARE'S-TAIL AND THE SPORES—COMMON SEA-WEEDS AND THEIR GROWTH.

On Plate IV. will be seen many examples of the curious vegetables called Algæ, which exhibit some of the lowest forms of vegetable life, and are remarkable for their almost universal presence in all parts of this globe, and also almost all conditions of cold, heat, or climate. Many of them are well known under the popular name of Sea-weeds, others are equally familiar under the titles of "mould," "blight," or "mildew," while many of the minuter kinds exhibit such capability of motion, and such apparent symptoms of volition, that they have been long described as microscopic animalcules, and thought to belong to the animal rather than to the vegetable kingdoms.

Fig. 1 represents one of the very lowest forms of vegetable life, being known to the man of science as the Palmella, and 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 Palmoglæa, or that green slimy substance which is so common on damp stones. When placed under the microscope, this plant is resolvable into a multitude of green cells, each being surrounded with a kind of 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 joined end to end.

One of the figures, that on the right hand, represents the various processes of "conjugation," *i.e.* the reunion and fusion together of the cells. Each cell throws out a little projection, which meet together, and then uniting form a sort of isthmus, cementing the two main bodies. By rapid degrees this neck widens, until the two cells become fused into one large body. The whole subject of conjugation is very interesting, and may be seen treated at great length in the Micrographic Dictionary of Messrs. Griffith and Henfrey, a work to which the reader is referred for further information on many of the subjects that, in this small work, can receive but a very hasty treatment.

Few persons would suppose that the slug-like object on 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 being. 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 volition, 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 "still" 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, they lose the cilia, become clothed with a strong envelope, and pass into the still 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, o. 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, &c. in the form of green dust, and has recently been found to be the first stage of lichens.

A large and interesting family of the "confervoid algæ," as these low forms of vegetable life are termed, is called the Desmidiaceæ, or in more common parlance Desmids. 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. For preservation, glycerine and gelatine seem to be the best fluids. A very full and accurate description of these plants may be found in Ralfs's "British Desmidieæ."

Fig. 4 represents one of the species of Closterium, more than twenty of which are known. 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. The 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 active moving bodies contained within it.

Fig. 16 is a supposed Desmid, called by the long name of Ankistrodesmus, and presumed to be an earlier tage of Closterium.

Fig. 6 is a very pretty Desmid called the Pediastrum.

and is 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 the continual subdivision of the contents of each cell into a number of smaller cells, termed "gonidia" on account of their angular shape. 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 the water supplied for drinking in London, as well as 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 grows 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, suffering 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 Oscillatoriæ, 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. Dr. Carpenter is ot opinion that the Oscillatoriæ may be the earlier or "motile" forms of some more perfect plants.

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 equa. 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 pattern; 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 separate the one from the other. Fig. 11 represents a portion of the Tyndaridea during the process of conjugation, showing the tube of connexion between the cells and one of the spores.

We now arrive at the Diatoms, so called because of their extreme brittleness and the ease with which they may be cut or broken into their component cells. The commonest of those plants is the Diátoma vulgáre, seen in fig. 21 as it appears while growing. The reproduction of this plant is 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 generally be distinguished. It also grows by conjugation. The diatoms are remarkable for the delicate shell of flinty matter which incrusts the cell-membranes, 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—Cocconéma lanceolátum—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 Gomphonéma acuminátum, found commonly in ponds and ditches. There are nearly forty species belonging to this genus. A pair of frustules are also shown which have been treated with nitric acid and heat, and exhibit the beautiful flinty outline without the coloured contents, technically called endochrome.

Fig. 27 is a side view of a beautiful diatom, called Eunótia diadéma 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. This specimen has been boiled in nitric acid.

Fig. 28 represents a very common fresh-water diatom, named Melosíra várians. 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, as it appears after having been subjected to the action of heat or nitric acid.

A rather curious species of diatom, called Cocconeïs pedículus, 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 and standing in place of 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.

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 go by the name of Naví cula, on account of their boat-like shape, and their habit of swimming 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. There seems to be but one species known.

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 a moderate power is used, it appears as shown in the figure, and always retains within its body a number of smaller individuals, which after a while burst through the envelope of the parent, and start into 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 affair 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. 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 spores, and supposed by some authors to be a state of the ordinary blue mould. Fig. 26 is a curious object, presumed to be one of the confervoid algæ, and found in the human stomach, where it probably gets by means of the water used for drinking. It may possibly be a blanched form of some fresh-water alga. Its scientific name is Sárcina ventrículi.

We now come upon a few of the Blights and Mildews. Fig. 32 is the Urédo, or red-rust of wheat. Another species is very common on the Bramble-leaf, where it appears in spots which at first are red, then orange, and at last become reddish black. Another species of Uredo, together with a Phragmídium, once thought to be another kind of fungus, is seen on a Rose-leaf on Plate V. fig. 1. On fig. 10, however, of the same plate, the Phragmidium may be seen proceeding from Uredo, thus proving them to be but two states of the same plant. Fig. 33 is the mildew of corn, called Puccinia by scientific writers. Another species of Puccinia, found on the Thistle, is shown in Plate V. fig. 7. Fig. 34 is the mould found upon decaying grapes, and called therefrom, or from the clustered spores, Botrýtis. Some of the detached spores are seen by its side. Fig. 35 is another species of the same genus, termed Botrýtis parasítica, and is the cause of the well-known "potato disease."

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, Polytríchum, 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, another moss, 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 just as a child's toy-gun discharges the arrow. Fig. 5 is a part of the leaf of the Sphagnum moss, 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 Equisétum, 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, which are called the sporangia, is seen in fig. 40. From the top of the table depend a number of tiny pouches, lying closely against each other, and containing 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 so as to 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 siliculósus, that is found parasitically adhering to large plants, and is given, in order to show the manner in which the extremities of the branches are developed into sporanges. Fig. 37 is a piece of the common Green laver, Ulva latíssima, 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," Porphýra laciniáta, 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.

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

Fig. 11 is the Sphaceláris, 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 on 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 Cerámium 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 Myrionéma, growing parasitically on the preceding plant.

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

Fig. 18 shows the Polysiphónia parasítica, 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 "ceramídium" 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 preparatory 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 sacs at the extremities of the branches.

Fig. 25 is the Cladóphora, a green alga, given to illustrate its mode of growth; and fig. 26 represents one of the red sea-weeds, Ptilóta élegans, beautifully feathered, and with a small portion given also on a larger scale, in order to show its structure more fully. A good contrast with 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 Delesséria sanguínea, 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 lacerátum, a plant belonging to the same family as the preceding. The specimen here represented has a gathering of spores upon the frond, in which state the frond is said to be "in fruit."

Fig. 27 represents a portion of the common Sea grass (*Enteromorpha*), so common on rocks and stones between the range of high and low water. On the left hand of the figure, and near the top, is a small piece of the same plant much more magnified, in order to show the form of its cells.

CHAPTER VI.

ANTENNÆ, THEIR STRUCTURE AND USE—EYES, COMPOUND AND SIMPLE—BREATHING ORGANS—JAWS AND THEIR APPENDAGES—LEGS, FEET, AND SUCKERS—DIGESTIVE ORGANS—WINGS, SCALES, AND HAIRS—EGGS OF INSECTS—HAIR, WOOL, LINEN, SILK, AND COTTON—SCALES OF FISH—FEATHERS—SKIN AND ITS STRUCTURE—EPITHELIUM—NAILS, BONE, AND TEETH—BLOOD CORPUSCLES AND CIRCULATION—ELASTIC TISSUES—MUSCLE AND NERVE.

We now take leave of the vegetables for a time, and turn our attention to the animal kingdom.

On Plate VI. may be seen many beautiful examples of animal structures, most of them being taken from the insect tribes. We will begin with the antennæ, or horns, as they are popularly termed, of the insect.

The forms of these organs are as varied as those of the insects to which they belong, and in most cases they are so well defined that a single antenna will, in almost every instance, enable a good entomologist to designate the genus to which the insect belonged. The functions of the antennæ are not satisfactorily ascertained. They are certainly often used as organs of speech, as may be seen when two ants meet each other, cross their antennæ, and then start off simultaneously to some task which is too much for a single ant. This pretty scene may be witnessed on any fine day in a wood, and a very animated series of conversations may readily be elicited by laying a stick across their paths, or putting a dead mouse or large insect in their way.

I once saw a very curious scene of this kind take place at an ant's nest near Hastings. A great Daddy Long-legs had unfortunately settled on the nest, and was immediately "pinned" by an ant or two at each leg so effectually, that all its struggles availed it nothing. Help was, however, needed, and away ran four or five ants in different directions, intercepting every comrade they met, and by a touch of the antennæ sending them off in the proper direction. A large number of the wise insects soon crowded round the poor victim, whose fate was rapidly sealed. Every ant took its proper place, just like a gang of labourers under the orders of their foreman; and by dint of pushing and pulling, the long-legged insect was dragged to one of the entrances of the nest, and speedily disappeared.

Many of the ichneumon-flies may also be seen quivering their antennæ with eager zeal, and evidently using them as feelers, clearly to ascertain the presence of the insect in which they intend to lay their eggs, and many other similar instances will be familiar to any one who has been in the habit of watching insects and their ways.

It is, however, most likely that the antennæ serve other purposes than that which has just been mentioned, and many entomologists are of opinion that they serve as organs of hearing.

Fig. 15, Plate VI., represents a part of one of the joints belonging to the antennæ of the common House-fly, and 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. Perhaps they may be avenues of sensation which are not possessed by the human race, and of which we are therefore ignorant. Fig. 17 represents a section of the antennæ of an Ichneumon-fly, to show the structure of these organs of sense.

We will now glance casually at the forms of antennæ which are depicted in the plate.

Fig. 1 is the antenna of the common Cricket, and consists of a vast number of little joints, each a trifle smaller than the preceding, so as to form a long, thread-like organ. Fig. 2 is taken from the Grasshopper, and shows the joints larger in the middle than at each end.

Figs. 3 and 5 are from two minute species of Cock-tailed Beetles (*Staphylínidæ*), which swarm throughout 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 before they are removed.

Fig. 4 shows the antenna of the Tortoise Beetle (*Cássida*), so common on many leaves, and remarkable for its likeness to the reptile from which it derives its popular name. Fig. 3 is from one of the Weevils, and shows the extremely long basal joint of these beetles, as well as the clubbed extremity. Fig. 7 is the beautifully notched antenna of the Cardinal Beetle (*Pyrochróa*), and fig. 11 is the fan-like antenna of the common Cockchaffer. This specimen is taken from a male insect, and the reader will find his trouble repaid by mounting one of these antennæ as a permanent object.

It may here be noticed that all these antennæ must be mounted in Canada balsam, as otherwise they will be too opaque for the transmission of light through their substance.

In many cases they are all the better for being soaked for some time in liquor potassæ, then dried between two slips of glass, then soaked in turpentine, and lastly put up in the balsam. Otherwise, their characteristics will be totally invisible under the microscope, and the observer will be as bewildered as a gentleman of whom I heard, who lately purchased a good microscope, and returned it next day as useless. The maker who had guaranteed it naturally thought that it had been injured by rough treatment, but finding that it performed well in his own hands, he inquired as to the details, and especially as to the object which it would not show. The answer was, that it would not exhibit the crystals of sugar. "How large a crystal did you try?" asked the optician. "A lump out of the sugar-basin," was the answer.

Fig. 12 is an antenna from one of the common Ground Beetles (*Cárabus*), the joints looking like a string of elongated pears. The reader will find that in beetles he is sure to find eleven joints in the antennæ.

Fig. 10 is the entire antenna of a fly (*Syrphus*), one of those pretty flies that may be seen hovering over one spot for a minute, and then darting off like lightning to hang over another. 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 Tortoiseshell Butterfly (*Vanessa*), showing the slender knobbed form which butterfly antennæ assume; and figs. 13 and 14 are specimens of moth antennæ, showing how they always terminate in a point. Fig. 13 is the beautiful feathery antennæ of the Ermine Moth (*Spilosóma*); and fig. 14 is the toothed antenna of the Tiger Moth (*Arctia caja*). 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 now arrive at the Eyes of the insects, all of which are very beautiful, and many are singularly full of interest.

In the centre of Plate VI. 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 of 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, and can be seen to great advantage in the Dragon-flies. The compound eyes may be considered as aggregations of simple eyes, set closely together, and assuming a more or less perfect six-sided form. Their numbers vary very greatly; in some insects, such as the common Fly, there are about four thousand of these eyes, in the Ant only fifty, in the Dragon-fly about twelve thousand, and in one of the Beetles more than twenty-five thousand.

Fig. 18 shows a portion of the compound eye of the Atalanta 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 (*Heliöphilus*), showing the nearly-squared facets, the tubes to which they are attached, and portions of the optic nerves. Fig. 23 is part of the compound eye of a lobster, showing the facets quite square. All these drawings were taken by the camera lucida from my own preparations, so that I can answer for their authenticity.

On Plate VIII. figs. 6 and 12, the reader will find two more examples of eyes, being in these cases 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 those of 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, as it appears perched on a prominence or "watch-tower," as it has been aptly named, for the purpose of enabling the creature to take a more comprehensive view of surrounding objects.

Returning to Plate VI., on fig. 12 we see a curiously branched appearance, something like the hollow root of a tree, and covered with delicate spiral markings. This is part of the breathing apparatus of the Silkworm, extracted and prepared by myself for the purpose of showing the manner in which the tubes branch off from the "spiracle" or external breathing-hole, a row of which may be seen along the sides of insects together with the beautiful spiral filament which is wound round each tube for the purpose of strengthening it. One of these spiracles may be seen in the neck of the Gnat (fig. 27). Another spiracle, more enlarged, may be seen on Plate VII. fig. 34, taken from the Wireworm, *i.e.* the larva of the Skipjack Beetle (*Eláter*), to show the apparatus for excluding dust and admitting air. The object of the spiral coil is very evident, for 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 bendings to which it may be subjected. Flexible tubes for gas and similar purposes are made after the same fashion, spiral metal wire being coiled within the leather case. A little piece of this thread is seen 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. I have succeeded in unwinding a considerable length of this filament from the breathing-tube of a Humble Bee.

Fig. 28 represents the two curious tubercles upon the hinder quarters of the common Green-blight, or Aphis, so very common on our garden plants, as well as on many trees and other vegetation. From the tips of these tubercles exudes a sweet colourless fluid, which, after it has fallen upon the leaves, is popularly known by the name of honey-dew. Ants are very fond of this substance, and are in the habit of haunting the trees upon which the aphides live, for the purpose of sucking the honey-dew as it exudes from their bodies. A drop of this liquid may be seen on the extremity of the lower tubercle.

The head of the same insect may be seen on fig. 24 where the reader may observe the bright scarlet eye and the long beak with which it 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 found upon the Tortoise, and remarkable for the powerful hooked apparatus which projects in front of the head.

Turning to Plate VII. fig. 4, we find the head of a Ground Beetle (*Cárabus*), valuable as possessing 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 in order to save room. Above these are two pairs of similarly constructed organs termed the "maxillary palpi," because they belong to the lesser teeth, or maxillæ, which are 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.

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 licking 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, and 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 the mandibles outside all.

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. 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 Atalanta Butterfly, being composed of the maxillæ very greatly developed, and having a form as if each had originally been flat, and then rolled up so as to make about three-fourths of a tube. A number of projections are seen towards the tip, and one of these little bodies is shown on a larger scale at fig. 3. These curious organs have probably some connexion with the sense of taste. Along the edges of the semi-tubes are arranged a number of very tiny hooks, by means of which the insect can unite the edges at will.

Fig. 11, in the centre of the plate, shows one of the most curious examples of insect structure, the proboscis or trunk of the common Bluebottle-fly. The maxillary palpi covered with bristles are seen projecting at each side, and upon the centre are three lancet-like appendages, two small and one large, which are used for perforating various substances on which the insect feeds. The great double disc at the end is composed of the lower lip greatly developed, and is filled with a most complex arrangement of sucking-tubes, in order to enable it to fulfil its proper functions. The numerous tubes which radiate towards the circumference are strengthened by a vast number of partial rings of strong filamentary substance, like that which we have already seen in the breathing-tube of the Silkworm. Some of these partial rings are seen on fig. 12, a little above. The mode by which the horny matter composing the rings is arranged upon the tubes is most wonderful, and requires a tolerably high power to show it.

Fig. 5 shows the tongue of the common Cricket, a most elegantly formed organ, having a number of radiating bands covered with zig-zag lines, resulting from 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 against each other. Around the pro-legs are arranged a series of sharp hooks, set with their points inwards, for the greater convenience of 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 (*Phalángium*), the whole structure looking very like the antenna of the cricket. 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 Trombídium, a genus of parasitic creatures, to which the well-known Harvest-bug belongs. Fig. 26, Plate VI., shows the leg of the green Aphis of the geranium, exhibiting the double claw, and the pad or cushion, which probably serves the same purpose as the pad 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 Típula has a foot also furnished with a single pad (see Plate VI fig. 30). This organ 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. Many of my readers will doubtlessly have noticed the common Fly towards the end of autumn, walking stiffly upon the walls, and evidently detaching each foot with great difficulty, age and infirmity having made the insect unable to lift its feet with the requisite force.

Fig. 21 is the foot of one of the Ichneumon-flies (*Ophĭon*), the hairy fringe being apparently for the purpose of enabling it to hold firmly to the caterpillar in which it is depositing its eggs, and which wriggles so violently under the infliction, that it would soon throw its tormentor, had not some special means been provided for the purpose of keeping its hold. Fig. 20 is a beautiful example of a padded foot, taken from the parasitic creature which is so plentifully found upon the Dor Beetle (*Geotrŭpes*), and of which the afflicted insect is said to rid itself by lying on its back near an ant's nest, and waiting until the ants carry off its tormentors.

Fig. 18 is the foot of the common yellow Dung-fly, so plentiful in pasture lands, and having two claws and two pads; and fig. 19 shows the three pads and two claws found in the foot of the Hornet-fly (*Ásilus*).

Few microscopic objects call forth such general and deserved admiration as the fore-foot of the male Water-Beetle (*Acilius*), when properly prepared and mounted, for which see fig. 13.

On examining this preparation under the microscope, it is found 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 a very 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.

The preparation of these feet is a very tiresome business, as the suckers hold so much air, that bubbles are constantly showing themselves, and cannot be easily extirpated without the expenditure of time and much patience. Two specimens of these feet which I prepared cost an infinity of trouble, having to be soaked in spirits of turpentine, boiled several times in Canada balsam, poked about with needles, and subjected to various treatments before they showed themselves clean and translucent, as they ought to do.

One of the larger suckers is seen more magnified on fig. 14.

Plate VIII. fig. 1 well exemplifies the manner in which the muscles of insects do their work, being well attached in the limbs to the central tendon, and pulling "with a will" in one direction, 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 (*Cássida*), the skin having being 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 Locust of England (*Ácrida viridíssima*). 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. 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 hollow branches or "nervures," which admit air, and serve 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 race into their different orders, as may be seen in any work on entomology. The primary number of wings is four, but it often happens that two are almost wholly absent, or that the uppermost pair are thickened into a shelly 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, and the lower pair are shrivelled and useless.

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 Aphis may be seen on fig. 24, very highly magnified.

Fig. 31 is the wing of the Midge (*Psychóda*), 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 Cíxius. 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 "haltéres" of the House-fly. These organs are found in all 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 Adippe or 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 on 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 Sugar-runner (*Lepisma sacchaˊrina*), a little silvery 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 not easy to catch with the fingers, as it slips through them like oil, but if the finger be afterwards examined, some of the beautiful scales will be found adhering, and may be placed under the microscope. The Gnats also possess very pretty scales, with the ribs projecting beyond the membrane.

Fig. 21 is a scale from the common Spring-tail (*Podúra plúmbea*), 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 little beings. 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 of the same family—the Weevils—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 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 Lepidóptera 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 fastened to a hair of a horse. Fig. 5 represents the pretty ribbed egg of the common Tortoiseshell Butterfly; and fig. 7 is the very beautiful egg of the very horrid Bed-bug, worthy of notice on account of the curious lid with which its extremity is closed, and by means of which the young larva creeps out as soon as it is hatched.

Fig. 9 shows the penetrating portions of the Sting of the Wasp. The two barbed stings, which seem to be the minute prototypes of the many-barbed spears of the South Sea Islanders, are seen lying one at each side of their sheath, and a single barb 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, causing its death in a short while.

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, from the eggs issue black caterpillar-like grubs, which devastate the bushes sadly, and in process of time turn into blackish flies, which are seen hovering in numbers over the gooseberries, and may be killed by thousands.

The scales and hairs of other animals deserve great attention. Fig. 23 is a single hair of the human beard, as it often appears when tied in a knot—by Queen Mab and her fairies, according to Mercutio. Fig. 22 is a portion of the same hair as it appears when splitting at its extremity. The structure of the hair is not, however, so well seen in this object as in that represented on fig. 24, which is a beautiful example of white human hair, that once adorned the head of the victor of Waterloo. It formed one of a tiny lock given to me by a friend, and is so admirable an example of human hair, that I forthwith mounted it for the microscope. In this hair the marrow-cells may be seen extending down its centre, and the peculiar roughened surface produced by the flattened cells which are arranged around its circumference are also seen. By steeping in caustic potash, these scales can be separated, but generally they lie along the hair in such a manner that if the hair be drawn through the fingers from base to point, their projecting ends permit it to pass freely; but if it be drawn in the reverse direction, they cause it to feel very harsh to the touch.

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; and 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 larger hairs that protrude so plentifully, and form the glistening brown coat of that animal. Fig. 38 is the curiously 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. 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.

The four fibres mostly used in the manufacture of apparel 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 mostly used in adulterations of silk and linen fabrics, and may at once be detected by its flat twisted fibre. Silk is always composed of two parallel threads, each proceeding from one of the spinnerets of the caterpillar, and it may be here remarked that if these threads are not quite parallel the silk is of bad quality. Silken fibre is always when new covered 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 (*Aphrodíte aculeáta*), 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 Fish 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. 15, and is a magnificent subject 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 some beautiful silvery crystals on the under surface of the scales, which were greatly used in the manufacture of artificial pearls, glass beads being thinly coated in the interior with the glittering substance, and then filled in with wax. A piece of Sole-skin, when preserved in Canada balsam and placed under the microscope, is a very beautiful object.

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 is greatly modified 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 by each other's 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, and so to render the whole feather 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, and 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 glue, letting them harden, and then cutting thin slices with a razor. A little water will dissolve the glue, 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 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 by flattened cells or scales, is consequently very thin, and is shown by the dark outline of the top. 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, being 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, which gives to the pupil that deep black aspect which it presents. The shape of the pigment particles is well shown. 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 peculiar form which is called "Epithélium," and which supplies the place of 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 nucleölus, or something which goes by that name, may be discovered with a little care. Cells of this kind are sometimes rounded, as in the case just mentioned, or angular, and in either case they are termed "pavement" or "tesselated" epithelium. Sometimes they are like a number of cylinders, cones, or pyramids, ranged closely together, and are then called cylinder epithelium. Sometimes the free ends of cylinder epithelium are furnished with a number of vibrating filaments or cilia, and in this case the structure is called "ciliated" epithelium. Cylinder epithelium may be found in the ducts of the glands which open into the intestines, as well as in the glands that secrete tears; and ciliated epithelium is seen largely in the windpipe, the interior of the nose, &c. A specimen taken from the nose is seen at fig. 15.

Bone in its various stages is figured on Plate X.

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

The large aperture in the centre is one of the innumerable tubes that run through the bone, and that 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 "lacúnæ," and the little black lines are called "canalículi." When viewed by trans mitted light, the lacunæ, together with the canaliculi, are black; but when the mirror is turned aside, and light thrown on the object by the condenser, 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 these 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 popularly call our 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, which causes the cells to swell up and resume to a degree their original rounded form.

It is worthy of remark that the animal form is built up of cells, as is the case with the vegetables, although the cells are not so variable in shape. They generally may be found to contain nuclei well marked, two or more being often found within a single cell, and in many cases the tiny nucleöli are also visible. Good examples of these cells may be obtained from the yolk of an egg, and by careful management they may be traced throughout every part of the animal form. The aid of chemistry is often needed in order to force the cells to exhibit themselves in their true forms.

The Teeth have many of the constituents of bone, and in some of their parts are made precisely after the same fashion. When cut, the teeth are seen to consist of a hard substance, called Enamel, which coats their upper surfaces, of 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, the enamel is seen above, the ivory occupying the greater part of the tooth, and the cement at the bottom. In the centre of each tooth there is a cavity, which is plentifully filled with a pulpy substance from which the tooth is formed. A transverse section of the same tooth is seen at 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 Ivory is composed of a substance pierced with myriads of minute tubes, which give out branches that communicate freely with each other. They require a rather high power—say 300 diameters—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 old 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. Sections of young bone form magnificent objects for the polariser.

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

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, 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 elastic ligament, popularly called "paxwax," taken from the neck of a sheep.

The white fibrous tissue by which all the parts of the body are bound together is seen at fig. 10; and at fig. 11 is a beautiful example of "ultimate" fibrous tissue taken from the crystalline lens of a Sturgeon's eye.

The muscles of animals are composed of two kinds of fibre, the one termed the striped, and the other the unstriped. Of these, the latter belongs to organs which work without the will, such as the stomach, &c., 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 simple fibres; 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 muscu lar fibre, taken from beef. When soaked in spirits, 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. Dissection of nerves is a tedious and difficult subject, and requires the aid of good books and instruments for its successful achievement.

The Blood of animals is analogous in its office to 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 chemical point of view. When a little recent 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 very 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 corpuscules are red, and give to the blood its peculiar tint. They are accompanied by certain colourless corpuscules, spherical in form, which are sometimes, as in man, larger than the red globules, and in others, as in the Siren and the Newt, considerably smaller. The general view of these red corpuscules 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 well marked 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 Siren and the Goat being, perhaps, the most decidedly opposed to each other in this respect.

In shape, those of the Mammalia are circular discs, mostly with a hollowed centre; those of the Birds are more or less oval and convex; those of the Reptiles are decidedly oval, very thin, and mostly have the nucleus projecting; and those of the Fishes are oval and mostly convex. During the process of coagulation, the blood corpuscules 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 corpuscules. 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, which cannot be described in these few and simple pages.

In the centre of Plate X. is a large circular figure representing 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 thin tape over the middle of the leg, and tie it down gently to the slide.

Bring the glass into focus, and the foot will present the appearance so well depicted in the engraving. The veins and arteries are seen spreading over the whole of the membrane, 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 reptile. It is a most wonderful sight, of which the observer is never tired, and which seems almost more interesting every time that it is beheld.

The corpuscules go pushing and jostling one another in the oddest fashion, just like a British crowd entering an exhibition, each one seeming to be elbowing its way to the best place. To see them turning the corners is very amusing, for they always seem as if they never could get round the smaller vessels, and yet invariably accomplish the task with perfect ease, turning about and steering themselves as if possessed of volition, and insinuating their ends when they could not pass crosswise.

By putting various substances, such as spirits or salt, upon the foot, the rapidity of the circulation can be greatly increased or reduced at will, or even stopped altogether for a while, and the phenomenon of inflammation and its gradual natural cure be beautifully illustrated. The numerous black spots upon the surface are caused by pigment.

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. The Frog, however, is perhaps the best, as it can be arranged on the "frog-plate" without difficulty, and the creature may be kept for months by placing it in a cool, damp spot, and feeding it with flies, little slugs, and similar creatures.

CHAPTER VII.

INFUSORIA—ROTIFERS—POND HUNTING—SPONGES—NOCTILUCA—SEA ANEMONES—JELLY FISH—FORAMINIFERA—ZOOPHYTES—ENTOMOSTRACA—LARVA OF CRAB—STRUCTURE OF SHELL—CILIA OF MUSSEL—STAR-FISHES AND ECHINI—PEDICILLARIA—CORALLINE—CAPILLARY VESSELS—INJECTIONS—COAL—GOLD-DUST AND COPPER—POLARIZED LIGHT.

TURNING back for a while to Plate IX. we come upon a series of objects which have long been termed Infusoria, because they are found in water in which vegetable or animal substances have been steeped. They get into almost every drop of water in which such substances have lain, and may be found even in the mud on the road or the roof-pipes of houses. Many of these curious beings are tolerably familiar to the public, through the medium of the oxy-hydrogen microscope so popular at exhibitions, and are generally supposed to be inhabitants of every drop of water which we drink. This, however, is not the case, as the water is always prepared for the purpose; hay, leaves, or similar substances being steeped in it for some weeks, and the turbid scrapings placed under the microscope to discompose the public mind. The whole history of these creatures is very obscure, and seems unlikely to be satisfactorily settled for the present. Suffice it to say that they may be found in almost every localityin every climate, being capable of withstanding cold far below zero and heat far above the boiling point, and may be dried over and over again, without seeming to care anything about the matter. Their increase is wonderfully rapid, taking place by subdivision, and thereby spreading the minute organisms throughout a large mass of water in an incredibly short space of time. So rapid is the process, that it may even be noticed under the microscope, and is remarkably interesting.

If a little hay or leaves be put into water, and suffered to remain in the open air for a week or two, a kind of deposit will collect round the decaying vegetation, and when submitted to the microscope is seen to contain a vast number of these minute but interesting beings. Many persons are fond of making skeleton plants by steeping them in water for a long time. The vessels in which this operation is performed are found to be extremely fertile in these curious little infusoria.

When some of the muddier portion of the water is placed under the microscope, it will be seen to be absolutely crowded with moving creatures, running restlessly in all directions, like Vathek and his companions in the Hall of Eblis, and in a similar manner avoiding each other, as if repelled by some innate force. On a closer examination, this moving crowd gradually resolves itself into variously shaped forms, among which one of the largest, and strongest, and swiftest is that which is represented in fig. 5, Plate IX., and is known by the name of Paramœcium.

It is one of a large family of Infusoria, the genera of which are reckoned at twelve in number. In size it is so large, that when the vessel of water is held between the eye and the light, it may be seen as a very minute white speck moving through the water. Its body is covered with vibrating cilia, by means of which it whirls itself through the water, and drives its food within reach of its mouth. The mode of action may be readily comprehended by putting a little carmine into the water, when the crimson particles will be seen hurled in regular currents by the cilia, and after awhile many will be distinguished within the transparent body. At each end of the Paramœcium there is a curious star-shaped, contractile vesicle. The cilia are arranged in regular rows. Three of the dart-like weapons with which it is armed are seen just below the figure.

Perhaps the lowest form of animal life is to be found in another of these Infusoria, the Amœba, which is represented at fig. 1.

This wonderful creature is remarkable for having no particular shape, altering its form momentarily, and moving by means of this curious mode of progression. At first it mostly looks like a little rounded semi-transparent mass, but in a short time it begins to push out one part of its body into a projection of some length, which gradually fixes itself to some convenient object, and by contraction draws the body after it. In fig. 1 three forms of the same creature are shown, one of which is remarkable for having included a large diatom in its structure.

The mode by which this creature feeds is the simplest imaginable. Any object which may serve as food, such as a diatom, a desmid, or another infusorial, comes in contact with the surface of its body, and is there held. Presently, that portion of the body whereon the captured organism lies begins to recede and forms a cavity, into which it is pressed. This cavity answers the purpose of a stomach, and the indigestible portions are either returned by the same way, or squeezed through some other portion of the animal. Such inclosed organisms may be seen in the figure.

At fig. 2 may be seen another curious creature named the Arcella, which is in fact little more than an Amœba with a shell, the soft body altering its shape in precisely the same manner.

A very curious Infusorial is shown at fig. 3. This is the Sun animalcule (*Actínophrys Sol*), remarkable for the long tentacles with which its body is surrounded. The nourishment of this creature is managed after the same manner as has already been mentioned when treating of the Amœba. The organisms which serve for its food are captured by one of the tentacles, which immediately begins to contract. Those surrounding it give their aid by bending towards it, and by their united force the victim is gradually pressed into the body, where it is digested.

Fig. 6 is given in order to show the process of subdivision as it takes place in the Infusoria. The species figured is the Chílodon, another flattened creature covered with cilia, with teeth arranged in the form of a tube, and with the fore part of the so-called head having a kind of membranous lip.

These creatures, together with many minute inhabitants of the waters, are of incalculable use in devouring the decaying substances that would otherwise breed pestilence, and converting them into their own living persons.

Figs. 7 and 10 represent two examples of the singular beings called Rotifers, on account of the wheel-like apparatus which they bear. Upon the front of the body or head is a retractile disc, whose edges are covered with cilia, which, by bending in regular succession, look exactly as if they were wheels running round at a great rate. A similar phenomenon may be seen in the corn-fields, when the wind forces them to bend, and produces a succession of waves that seem to roll over the field. These cilia are their chief modes of progression; but in many cases they get along rather fast by attaching their tails and heads alternately to the substances on which they move, after the well-known fashion of the leech, to which they then bear no small resemblance Fig. 10 represents the commonest species of rotifer, *Rótifer vulgáris,* in which this mode of progression may be seen.

They are furnished with a well-defined mouth and digestive organs, and their teeth, a pair of which may be seen in fig. 11, are very powerful.

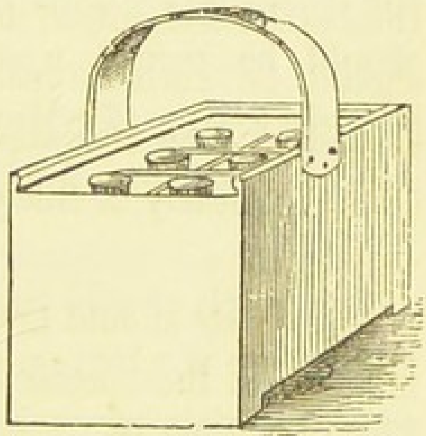
Some species of Rotifer, such as Melicerta, fig. 7, are inclosed in a tube. In some cases, as in the present, the tube is opaque; but in many it is beautifully transparent, and permits the inclosed creature to be seen through its substance.

I would that rapidly narrowing space did not compel me to give such brief notice of these most interesting creatures. They may, however, be readily obtained in almost any pond, provided the water be not putrid, and are so large that their movements may be watched with a rather low power. There are very many species, but they may be distinguished from the other inhabitants of the waters by the wheel-like processes from which they derive their name. Sometimes the wheel-disc is withdrawn within the body; but if the observer wait for a little while, he is sure to see the disc protruded and the wheels run their merry course.

The mode of obtaining these tiny creatures is sufficiently simple.

Get a small, rather wide-mouthed phial, and with the piece of string which every sensible man always has in his pocket, lash the bottle by the neck across the end of a walking-stick. Look out for the best hunting-grounds in ponds, rivulets, &c., an accomplishment in which practice soon makes perfect; push the inverted bottle among the flocculent greenage or the decaying leaves, and after poking it well about, turn the bottle suddenly over, when the water will rush rapidly in, carrying with it myriads of minute organisms. After a little experience in this kind of fishing, it soon becomes easy to capture any creature that may be seen in the water, by placing the inverted bottle delicately near the intended victim, and then quietly turning it over without alarming the easily frightened creature.

When the bottle is filled, the contents should be poured into another wide-mouthed bottle, and the process repeated until a sufficient amount of living organisms has been obtained. The bottle should always be labelled with the particular place, pond, or stream whence the water was obtained; and it is always well to add the date. It will be found advisable to have a number of wide-mouthed bottles always ready, which can be carried in a basket or box fitted up for the purpose by means of wooden partitions, or even by strings crossing each other at proper intervals. One reason for this precaution is the power of



identifying the exact locality in which any rare or curious creatures may be found; and another reason is, that the inhabitants of different ponds or puddles are apt to wage deadly war if put into the same bottle. A drawing of a case fitted up with bottles is here introduced, more for the purpose of giving the reader a model on which to make a hunting-case for himself, than to recommend him to purchase or order it from a carpenter

The air must always be admitted freely into the bottles, or the creatures will soon die. But as the conveyance of uncorked wide-mouthed bottles half full of water is exceedingly inconvenient, it is needful to fill up each bottle in such a manner that the air can be freely admitted, while the water will not run out.

A very simple contrivance is to close the mouths of the bottles with corks, to bore a hole through the centre of each cork, and to pass a quill through it, projecting about half an inch through the cork within the bottle, and cut off level above. Even if the bottle should be turned upside down by any mischance, scarcely a drop of water will escape; while the air is admitted nearly as freely as if the mouth of the bottle were open.

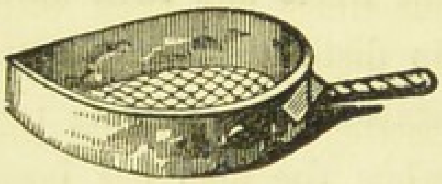
One bottle should be supplied with some of the mud taken from the bottom of the pool or puddle, as it is sure to contain many interesting objects, and is generally a rich preserve of the flinty skeletons of these little inhabitants of the waters.

They are easily separated from the other constituents of the mud, by putting a little of the mud into the bottom of a tall test-tube, pouring some nitric acid upon it, and boiling it gently over the flame of the spirit-lamp. Very great care is needed in this operation, as the liquid is apt to rise suddenly and boil over; and the fumes which arise are always copious and very deleterious, so that the boiling should always be done in the open air, or at all events in some place where the fumes can be carried away as fast as they are generated.

After it has boiled for some little time, and got cool, half fill the tube with distilled water, shake it up well, and set the tube upright so as to let the solid particles sink to the bottom. When it has thoroughly settled, which will not be for some hours, remove the clear liquid by means of a syphon—a wet skein of cotton thread hung over the edge of the tube will do very well—pour in some fresh nitric acid, and boil it again. Repeat this process three or four times, and then wash the residue very thoroughly in distilled water, always allowing the solid matter to settle, and removing the liquid with a siphon; and when the acid has been entirely washed away, spread some of the residue upon a clean slide, and examine it under the microscope. The field of the instrument will then be filled with the lovely flint scaffolding upon which the living organisms of these minute creations are supported; and when some peculiarly good specimens are found, they should be preserved as permanent objects by dropping a little Canada balsam upon them and mounting them after the manner already described.

There is a considerable amount of amusement to be got out of this kind of fishing, as it is always a sort of lottery, in which the blanks are none, and the prizes many.

For the capture of the larger creatures, such as are readily visible to the naked eye, and swim with much velocity, a net is needful. This is readily made by twisting a piece of brass or copper wire into a ring, and sewing a piece of very fine net over it so as to give it a hollow about as deep in proportion as that of a watch-glass. This little net can easily be carried in the pocket, and when wanted can be attached to a stick at a moment's notice.



A very useful little net, which, however, requires the aid of the tinman, is here depicted. The reader will see that it is made of a strip of tin bent into a spoon-like shape, and with a net fastened at the bottom. The great advantage of this net is that the high walls are very effectual in inclosing any quickly moving creature, and prevent it from being washed out of the net on its being raised to the surface. The meshes of the net need not be very close, as a mesh will always secure an insect of only half its diameter.

It is convenient for many reasons to have the nets and other apparatus made in such a manner that they can be carried without attracting observation, for at the best of times the microscopic angler is sure to be beset with inquisitive boys of all sizes, who cannot believe that any one can use a net in a pond except for the purpose of catching fish, and is therefore liable to have his sanity called in question, and his proceedings greatly disturbed. However, by a little judicious administration of "soft sawder" and a few pence, the enemies may generally be converted into allies, and rendered extremely useful.

Sponges and their structures are very interesting. They consist chiefly of a very thin gelatinous substance not unlike that of the Amœba, which is spread over a horny skeleton, which skeleton is sustained by an internal arrangement of spiculæ, mostly of a flinty nature, but sometimes being chalky in their substance. The gelatinous envelope is covered with cilia, by means of which the water is forced to circulate throughout the entire sponge, entering through the little apertures and being expelled through the larger holes. A portion of this substance with its cilium is shown at fig. 12. Fig. 14 shows this process in a Sponge (*Grántia*).

The little granules which afterwards become mature sponges are also thrown from the parent in the same manner. One of these bodies covered with cilia is shown at fig. 18. When ejected from the parent, they swim merrily about for some time, but at last settle down and become fixed for the rest of their life. During the life of a sponge it is coloured, and often vividly, with various tints; but after the death of the living portion, the bare horny skeleton is left.

Two forms of sponge spiculæ are shown at figs. 8 and 20. The shapes, however, which these curious objects assume are almost innumerable. In them may be seen accurate likenesses of pins, needles, marlinspikes, cucumbers, grappling-hooks, fish-hooks, porters'-hooks, calthrops, knife-rests, fish-spears, barbed arrows, spiked globes, war-clubs, boomerangs, life-preservers, and many other indescribable forms. They may be obtained by cutting sponge into thin slices, and soaking it in liquor potassæ or any other substance that will dissolve the horny skeleton and leave the flinty spiculæ uninjured.

Every one 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

Noctilúca, 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.

In my "Common Objects of the Sea Shore" the Actíniæ 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.

The Jelly-Fishes, or Medúsæ, are partially represented at fig. 28, &c. This represents a very small and very pretty Medusa, called Thaumántias. When 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. The reproduction of these creatures is too complicated a subject for the small space allowed in these pages, but is partially illustrated by figs. 26 and 27. Fig. 26 is the Hydra tuba, a creature long thought to be a distinct animal, but now known to be the young of a Medusa, which does not itself attain maturity, but throws off its joints, so to speak, each of which becomes a perfect Medusa. One of these joints is shown at fig. 27.

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. Their real position in the animal kingdom is somewhat doubtful. The holes are intended to permit the passage of certain thread-like tentacles, and are variously arranged upon the shell. Chalk is largely mixed with these minute shells, and whole tracts of country are composed almost wholly of these little creatures in a fossilized state. They may often be found in sand, and separated by spreading the sand on black paper and examining it with a glass. Examples of these creatures are given in Plate IX. fig. 4 (*Miliolína*), and Plate XII. fig. 7, which is a portion of the shell to show the holes, fig. 13 (*Polystomella*), fig. 14 (*Truncatulína*), fig. 15 (*Polymorphína*), fig. 16 (*Miliolína*, partly fossilized), fig. 18 (*Lagēna*), and fig. 20 (*Biloculína*).

The Zoophytes or Polypi 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 polýpidon. 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 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. Fig. 19 is a very curious zoophyte called Anguinaria, or Snake-head, on account of its shape, the end of the polypidon 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; and fig. 24 is called the Tobacco-pipe zoophyte.

Fig. 22 is a portion of the Bugularia, 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 XII. as they appear under polarised light. Fig. 17 is the Cellularia reptans; and fig. 20 is the Bowerbankia.

Our space is so rapidly diminishing, that we can only give one example of the curious group of animals called Entomóstraca. They belong to the great class of Crustaceans, and are found both in fresh and salt water. Their shell is often transparent, so as to permit their limbs to be seen through its substance, and when boiled it gets red like that of the lobster. Their shape is extremely various, but that of the example at Plate IX. fig. 31, the Fresh-water Flea (*Daphnia*), affords a good illustration of their general appearance. The Cyclops, another fresh-water example, is very common in our ponds, and may be known by the long body, the single eye in the head, and the egg-bags depending from the sides of the females.

Fig. 25 is the larva of the common Crab, once thought to be a separate species, and described as such under the title of Zoea. I may as well mention that many of the objects here mentioned in a cursory manner are to be found described more at length in my two previous manuals, the "Common Objects" of the Sea-shore and Country.

Parts of the so-called feet of the Serpula are shown at fig. 36, where the spears or "pushing-poles" are seen gathered into bundles as used by the creature One of them on a larger scale is shown at fig. 32.

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.

Before entering upon the Echinoderms, we will cast a glance at a beautiful structure found upon the gills of the common Mussel. Fig. 39 shows a portion of the gills in order to exhibit the numerous cilia with which it is covered. It is a valuable example, as the cilia attain a very large size on this organ, being about one five-hundredth of an inch in length. Their object is of course to produce circulation in the water which bathes the gills.

The old story of the goose-bearing tree is an example 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 one whit a stranger tale than the truth. Plate IX., fig. 33, shows the young state of one of the common Star-fishes (*Comátula*), 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 to that which characterizes the barnacles and sponges, where the young are at 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 Ophiúra, 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 Pedicillariæ. These are found on Star-fishes and Echini, 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 object is doubtful, unless it be to act as police, and by their continual movements to prevent the spores of algæ, or the young of various marine animals, from effecting a lodgment on the skin. A group of Pedicillariæ from a Star-fish is shown on a large scale on Plate XII. fig. 6, and fig. 9 of the same plate shows the Pedicillariæ of the Echinus.

Upon the exterior of the Echini or Sea-Urchins are a vast number of spines, 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 species. 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 madrepore-like 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 polarizer.

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 similitude to fig. 22, the Sea-mat zoophyte. Fig. 23 is a portion of the skin taken from the 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 needs tools of some cost. 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 becom filled with coagulated blood, so as to form what is called a natural injection, ready for the microscope.

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.

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 appliance of the apparatus is very simple. It consists of two prisms, one of which, called the polarizer, is fastened by a catch 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 powers, one class of objects from another.

Another instrument really essential to the microscopist is the micrometer, for the purpose of measuring the minute objects under examination. The cheapest and simplest is the Stage Micrometer, which may be purchased for five shillings at the opticians'. It consists simply of a glass slide on which are ruled a series of lines, some the hundredth of an inch apart, and others the thousandth. This is laid on the stage, and the object placed upon it, when with a little management the lines may be made to cut the objects so as to give their dimensions.

Another simple and even more accurate way is to slip the camera lucida on the eye-piece, and sketch the object as mentioned on page 51. Then remove the object, substitute the stage micrometer, and sketch the lines upon the drawing of the object. It will be also evident that if the "hundredth" lines coincide with an inch, the object is magnified one hundred diameters; if with two inches, two hundred diameters, and so on.

INDEX.

DESCRIPTION OF PLATES.

I.

II.

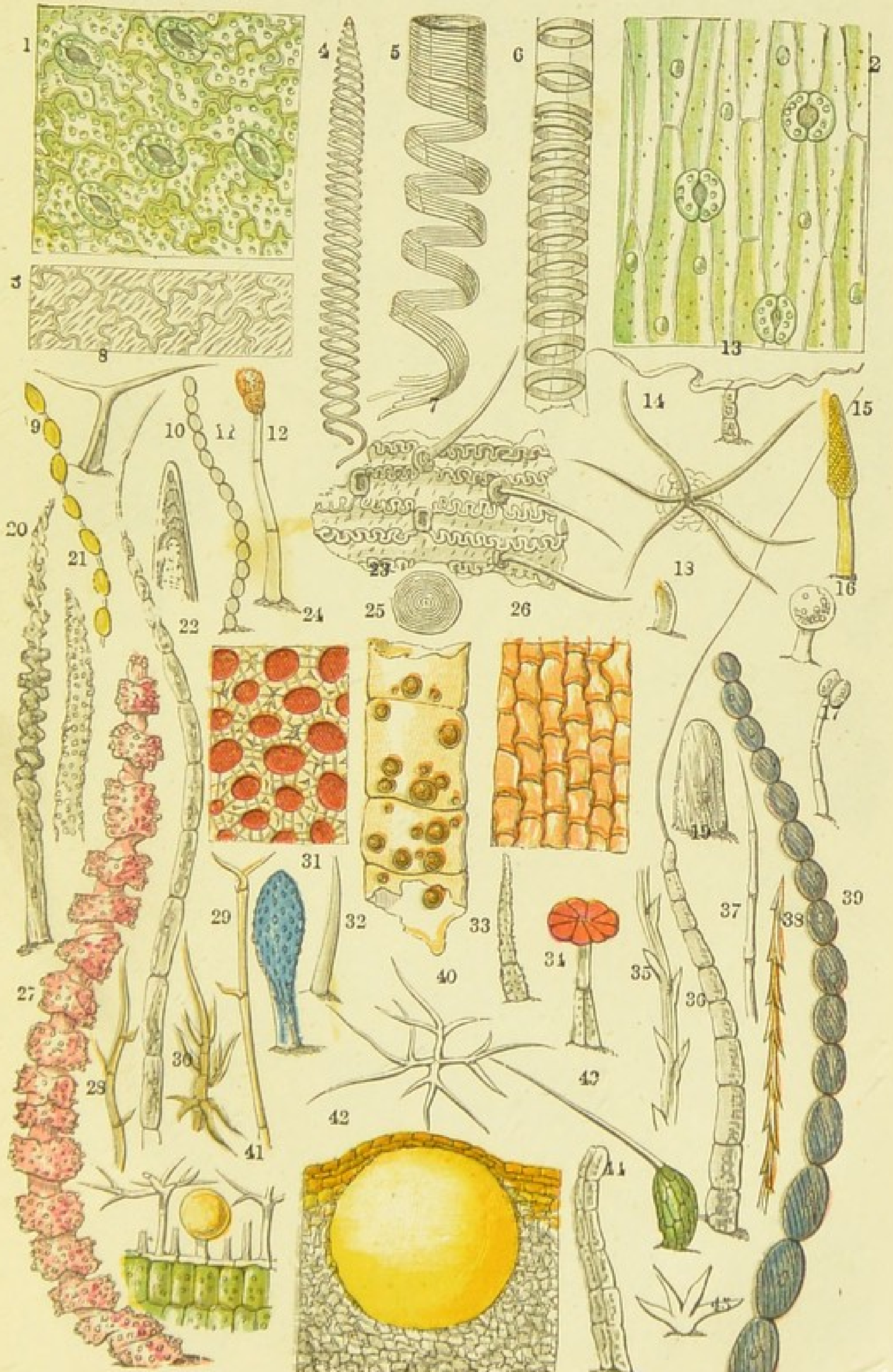
III.

XI.

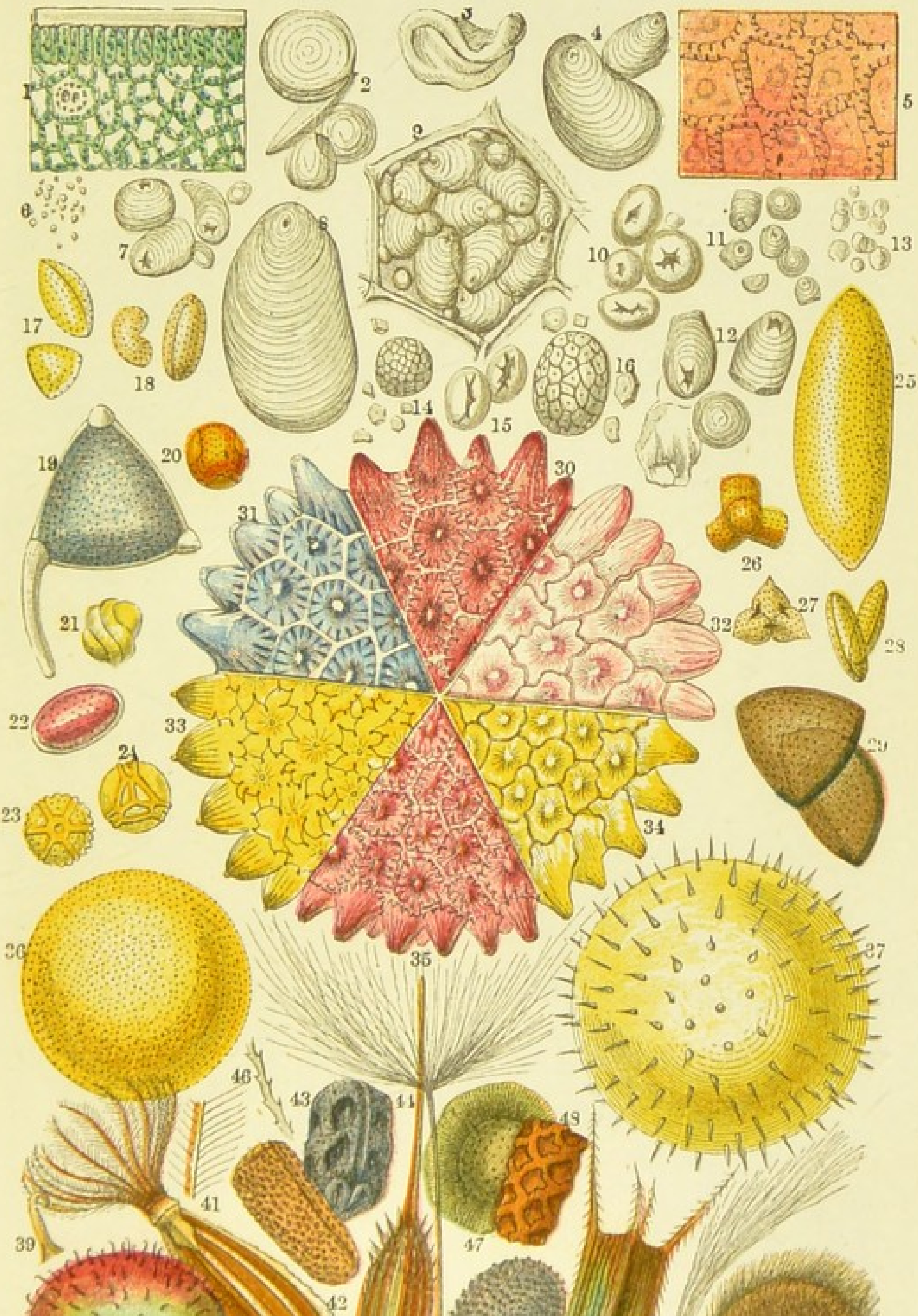
POLARIZED LIGHT.

XII.

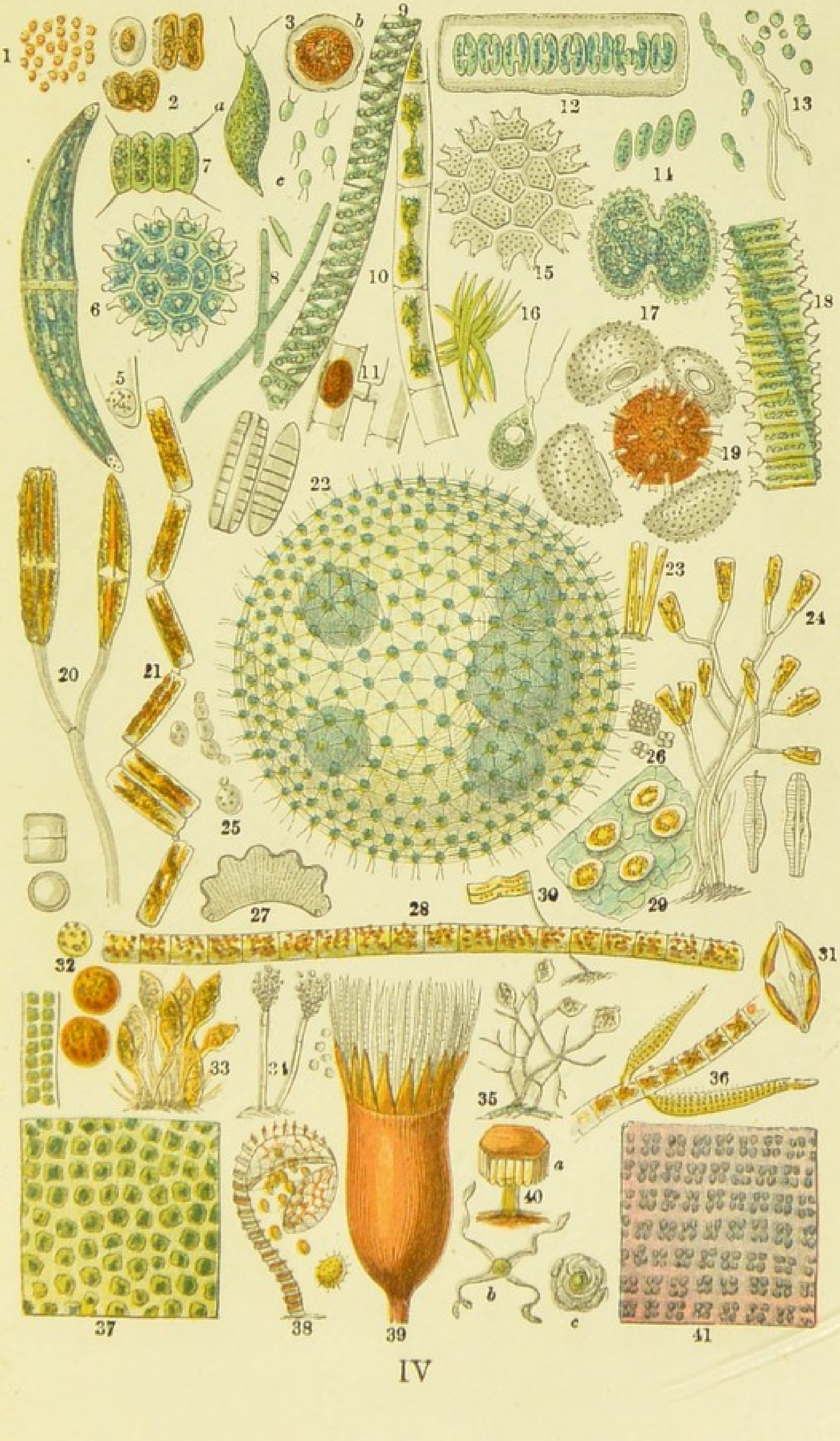
Woodfall & Kinder, Printers, 70 to 76 Long Acre, London, W.C.



11.

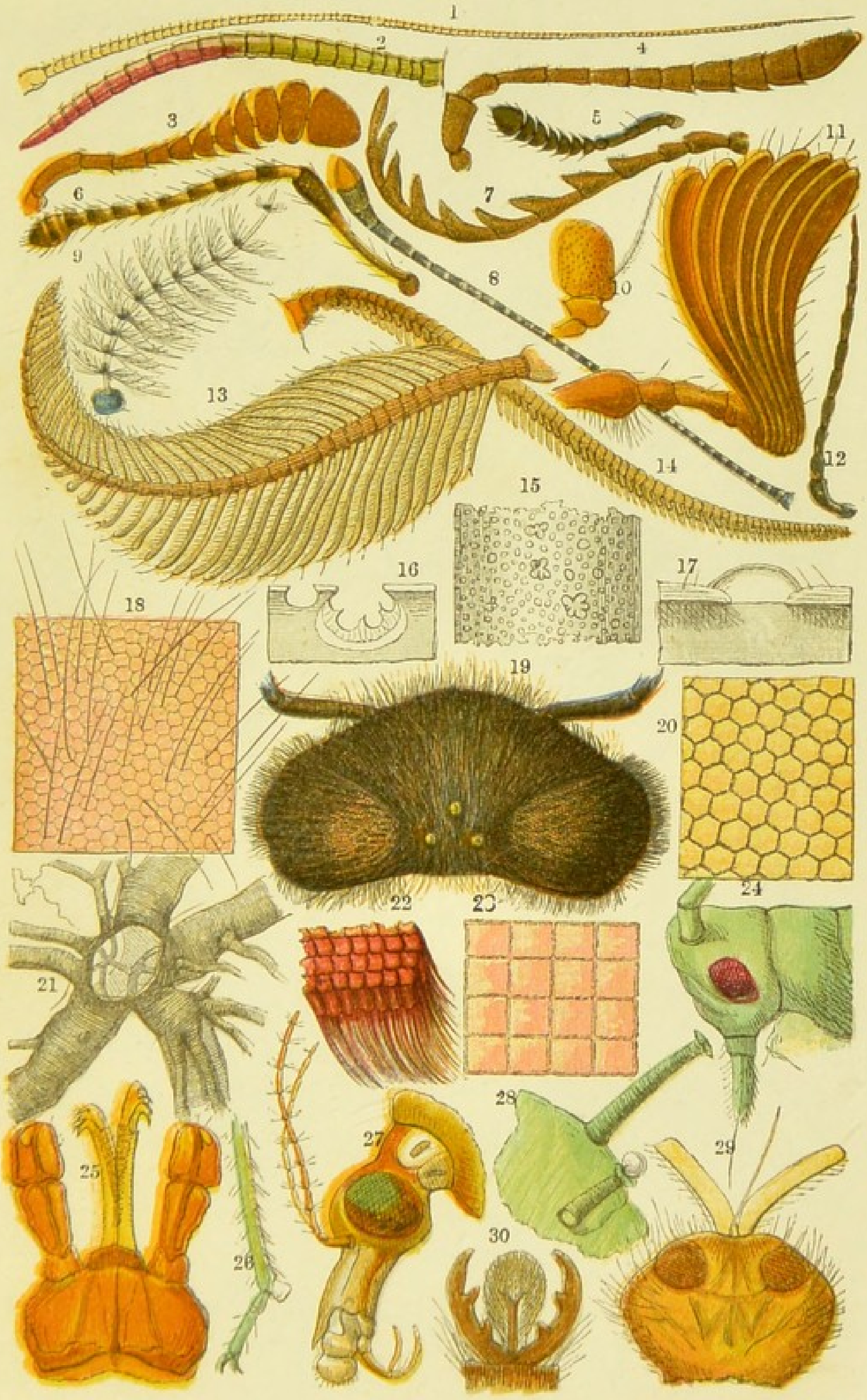

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52

III.


1
2
3
a
b
c
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41

IV

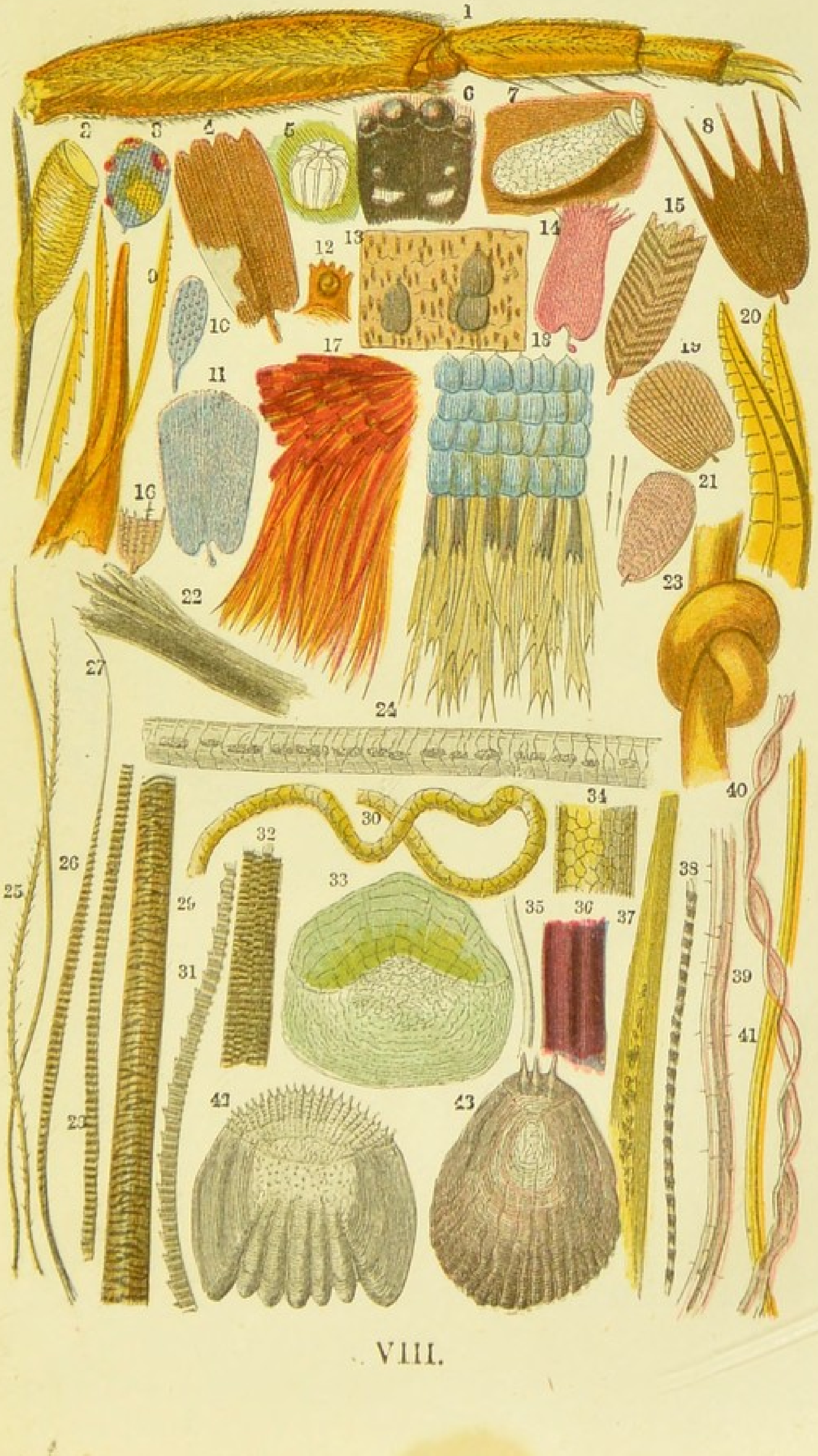
V.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

VI.


1
2
3
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

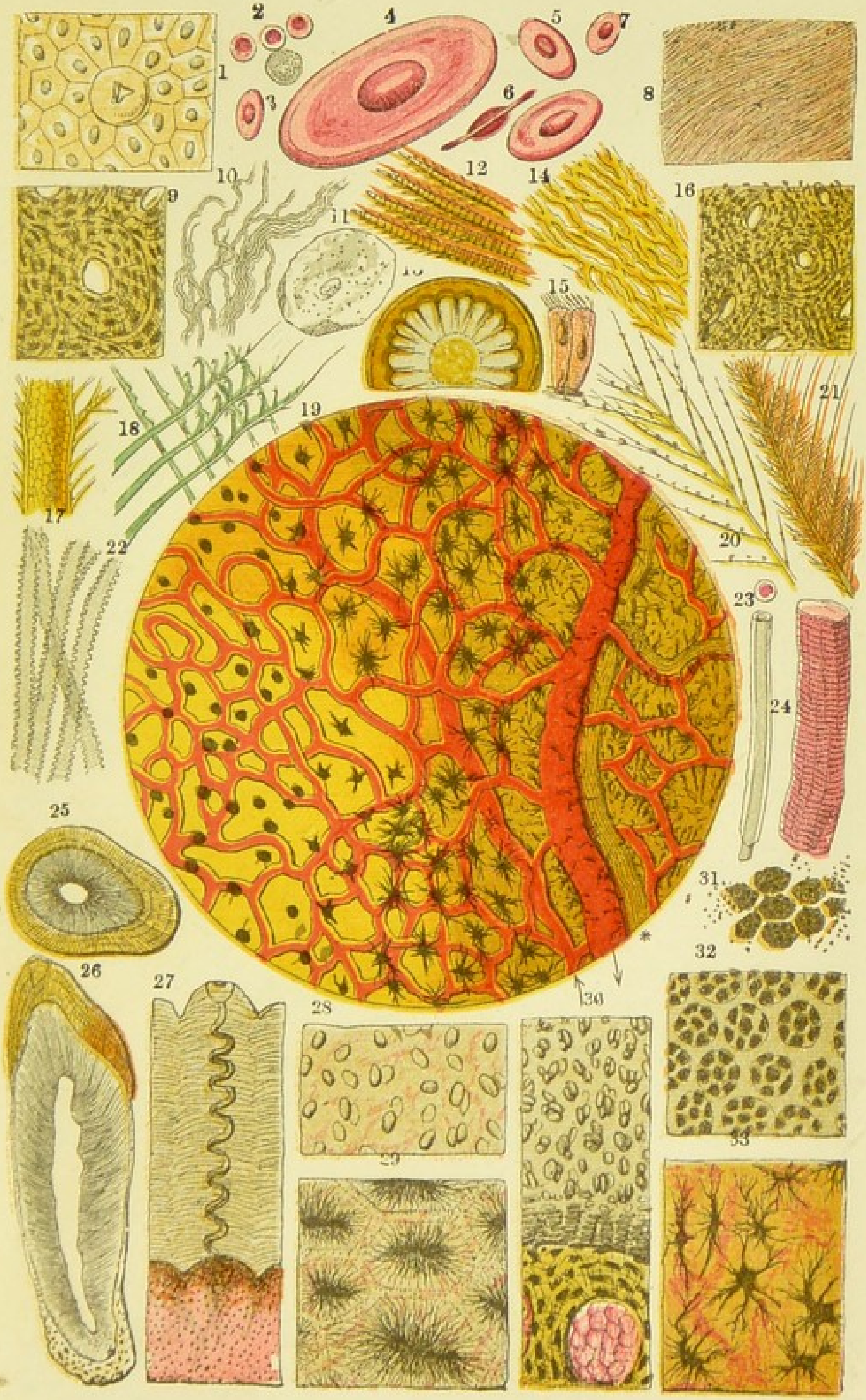
VII.



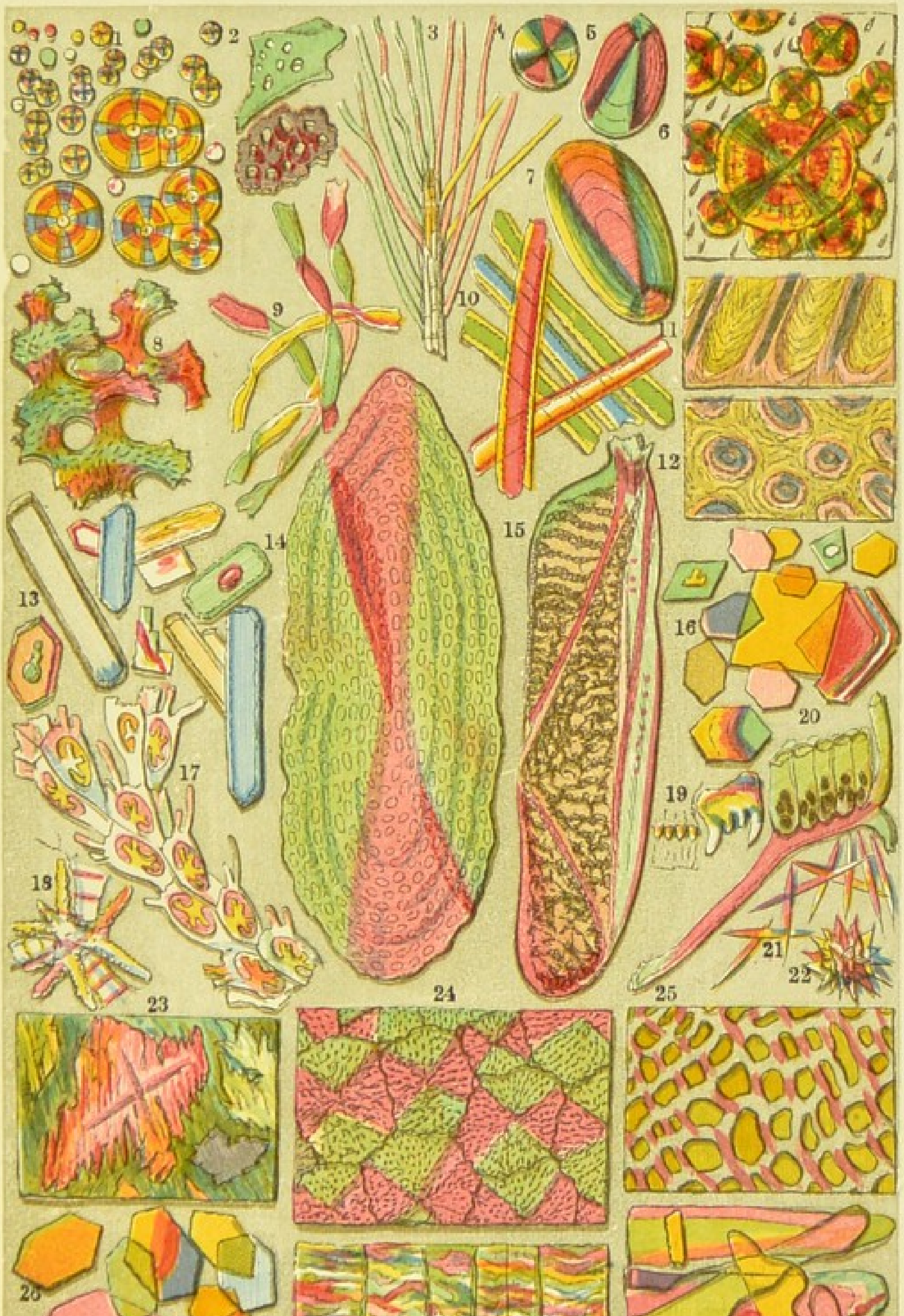
VIII.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39

IX.


1
2
3
4
5
6
7
8
9
10
11
12
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
30
31
32

X



XI.

XII.