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THE MICROSCOPE

AND SOME OF THE WONDERS IT REVEALS

BY THE
REVD
W. HOUGHTON

THE
MICROSCOPE,
AND SOME OF THE
WONDERS IT REVEALS.

BY

REV. W. HOUGHTON, M.A., F.L.S.

Illustrated.

CASSELL, PETTER, AND GALPIN,
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THE MICROSCOPE.

CHAPTER I.

INTRODUCTORY.

I AM supposing, reader, that at present you are almost, if not altogether, unacquainted with the use of that wonderful instrument by means of which objects quite invisible to the unassisted eye become distinctly seen, and their minutest structure understood. It will be my endeavour in this little Elementary Hand-book on the Microscope, its construction and revelations, to put you in possession of such knowledge as shall serve as a basis for further information, and a stimulant to unceasing inquiry.

The word *microscope* is of Greek origin, being derived from two words, μικρός, "small," and σκοπέω, "I view." Its name, you will see at once, most appropriately describes its use. I need say very little of its history. Simple microscopes or magnifying-glasses were known to the ancient Greeks and Romans; while compound microscopes were not invented before the end of the sixteenth century. In process of time this instrument, through the successive labours of various men of different ages, has become developed into a very valuable instrument of scientific research, whilst the success that has crowned the efforts of microscope-makers during the last thirty years has been truly marvellous. There is one point in the history of the microscope which it would be well to bear in mind, because it may show you how much may be done by honest and persevering workers with even inferior instruments. Those who are acquainted with the researches of Leuwenhoek, Grew, and Malpighi, all frequent writers in the early volumes of the *Philosophical Transactions*, are struck with astonishment at the discoveries they made with instruments so much inferior to those in use at the present day. Truly has an eminent living microscopist and biologist observed with regard to the researches of Leuwenhoek, "That with such imperfect instruments at his command, this accurate and painstaking observer should have seen *so much* and *so well* as to make it dangerous for any one, even now, to announce a discovery without having first consulted his works, in order to see whether some anticipation of it may not be found there, must ever remain a marvel to the microscopist." Of the labours of Grew and Malpighi the same writer remarks—"Both were attended with great success. The former laid the foundation of our anatomical knowledge of the vegetable tissues, and described their disposition in the roots and stems of a great variety of plants, besides making out many important facts in regard to their physiological action; the latter did the same for the animal body, and he seems to have been the first to witness the marvellous spectacle of the movement of blood in the capillary vessels of the frog's foot, thus verifying by ocular demonstration that doctrine of the passage of blood from the smallest arteries to the smallest veins, which had been propounded as a rational probability by the sagacious Harvey."*

A *simple* microscope is familiar to everybody in the

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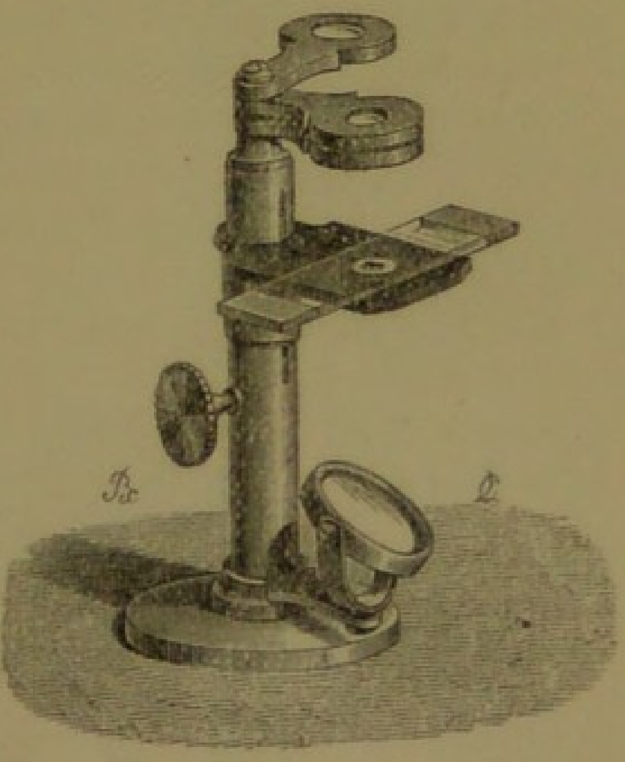
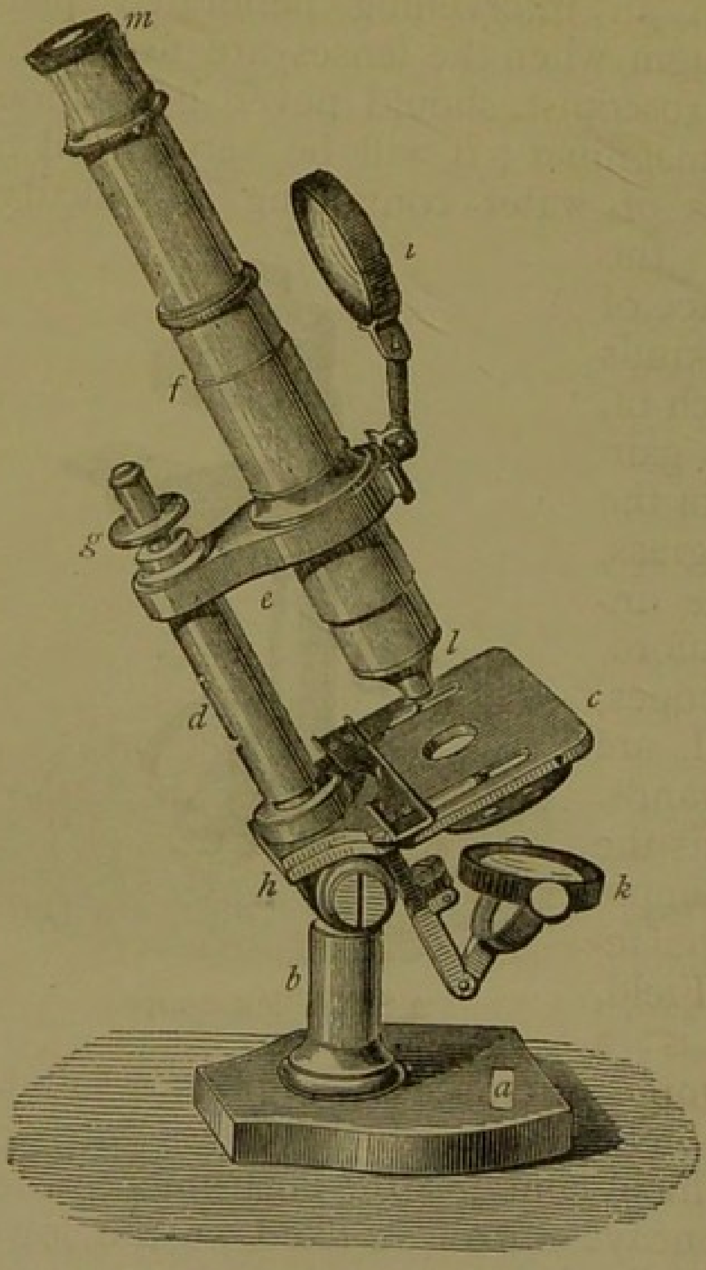
* Carpenter on the Microscope, third edition, p. 2, Introduction.

form of a reading-glass or hand-magnifier; perhaps the most useful form for the pocket consists of one or more lenses, which shut up in a tortoiseshell or horny frame, with an intervening perforated plate to act as a diaphragm when the lenses are used altogether. The microscopist should never be without this little pocket-magnifier; it will be very useful in examining samples of water containing animalculæ, revealing to him the presence or absence of some particular kinds he may be in search of, or enabling him to gain some clearer idea of the structure of a fern, grass, or flower, than the unaided eye can afford. Simple microscopes, properly so called, are supported on stands. That one known as the Society of Arts Simple Microscope, manufactured by Mr. Field, of Birmingham, is a useful form of simple microscope. It has a tubular pillar about five inches high, which screws into the lid of the box which contains the instrument when not in use; a concave mirror is fixed at the lower end of the pillar, while the upper end carries the stage and a short horizontal arm in which the lenses, three in number, may be screwed. A condensing lens, for opaque objects, can be fitted into any of the four holes with which the stage is perforated. This instrument has a range of powers from 5 to 40 diameters.



A Simple Microscope.

What is the difference between a simple and a compound microscope? It is this: in the simple microscope you look *directly*, through the lens, *at the object;* in the compound microscope you do not look directly at the object, but *at its image*, which has been magnified by another lens placed between the object and the lens, or "eye-piece," through which you are looking. Of course, great magnifying power is thus obtained.



A Compound Microscope.

Here is a figure of a microscope; it represents Nachet's smaller compound microscope. From a careful study of this figure you will soon be able to learn the parts of which it consists, and will gain a general idea of what a compound microscope is. It stands, as you see, on a broad foot, *a*, out of which a pillar, *b*, arises; at the top of this is a joint, *h*, supporting the stage, *c*, and another pillar, *d*, which carries the body, *f*, with which it is connected by a transverse arm, *e*. The body slides up or down within the ring of the transverse arm, like a telescope; this motion is for coarse focussing. For fine adjustment it is moved by a milled head, *g*, which acts upon a screw inside the pillar *d*. The joint at *h* enables the observer to place the instrument at any angle he may require. The mirror, for throwing light *through* transparent objects, is seen at *k*; a condensing lens, for throwing light *upon* opaque objects, is seen at *i*. So much for the mechanical arrangement. But where are the most important parts of the microscope—the lenses, upon the combination of which the magnifying power of the instrument depends? These lenses, which are known by the names of "object-glasses" and "eye-pieces" respectively, fit, the former by a screw, into the bottom of the body, *l*; the latter, *m*, by sliding into its top portion. I would advise you to learn the names of these different parts of a compound microscope. Of course, I need hardly tell you that there is great difference in the forms of compound microscopes, their mechanical arrangements, and so on; but the above description will serve to give you a fair idea of the general plan of a compound microscope.

Let us now look a little more closely into the structure of the lenses, on which the magnifying power of the microscope depends. I have already told you that these are known by the names of "eye-pieces" and "object-glasses," or "objectives," as they are sometimes termed. The names are easy to remember and explain their respective uses, the former being looked through by the *eye* of the observer, the latter being placed near the *object* you wish to examine. The ordinary eye-piece consists of two plano-convex* glasses, the plane surfaces of each being directed upwards. That one near the eye is the "eye-glass," the one at

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* A plano-convex lens is one which has one of its surfaces plane or flat, the other convex.

the greater distance is called the "field-glass." The object-glasses consist of three lenses, one of which is constructed to correct certain optical defects or "aberrations." Each of these three sets of lenses is itself compound; and upon the excellence of the lenses especially the merits of a good microscope depend. They ought to define objects with great clearness; there must be no haziness about the outlines of the images, and plenty of light must be secured. If you notice any coloured rings encircling any object you are inspecting, your object-glass must be discarded; it has not been corrected for this defect, which is known as "chromatic aberration," and will prove of no value to you. The microscopist will find two object-glasses quite sufficient to begin with; perhaps the inch, which will magnify, with No. 1 eye-piece, 30 or 40 diameters, and the quarter of an inch, which, with the same eye-piece, will give a power of about 200 diameters, will be found the most generally useful.

I need hardly tell you that a microscope should be perfectly steady, whether the body be inclined at any angle or stand in a vertical position; no vibration should be communicated to the body when the adjustment screws are turned for the purpose of focussing. Every microscope should be capable of being used in three different positions—vertical, inclined, and horizontal. Nachet's microscopes formerly could be used only with the body in a vertical position—one which is very trying to the muscles of the neck of the observer if he is working for some hours at a time; they are now made to assume the three positions. Then, again, the stage is a very important part of the instrument; it should be three inches long, by two and a half broad. Nachet's instruments are too small for working conveniently. Underneath the stage of every microscope there should be a revolving circular plate, called a *diaphragm*, in which there are holes of various sizes for the regulation of the required light for transparent illumination; the observer, however, will often find he can obtain just the quantity and quality of light required without a diaphragm, by inclining the mirror at various angles, or by shading it occasionally with the hand. A beginner will often find difficulty in getting the focus. Many instruments are provided with two adjustments for altering the focus; these are the coarse adjustment, which is effected by rack-and-pinion motion; and the fine adjüstment with very delicate motion. In some microscopes the coarse adjustment is obtained by moving the body of the instrument with the hand, as in the figure represented; but that effected by the rack and pinion is far more pleasant to use.

For the illumination of opaque objects, the condensing lens attached to the instrument will be found useful, but, in addition to this, it is very desirable to employ another condensing lens, mounted on a separate stand, and readily moved in any direction. That known as the *bull's-eye* condenser is very convenient and useful; the lens is a plano-convex one, about three inches in diameter, having a short focus. This lens must be turned with its plane surface to the light or lamp, and its convex side towards the object on the stage of the microscope—experience will determine the requisite distance: the rays of light passing through the bull's-eye will form a bright luminous spot upon the object. There are various other contrivances for illuminating opaque objects, but the beginner need not trouble himself with them; the more simple and the fewer the appliances, the more progress the student will at first make. I have enumerated, I think, nearly all the apparatus you will find *necessary*, unless I mention a *camera lucida*, or a *neutral tint glass* *reflector*, for drawing the outlines of the magnified images, or for measuring the objects. The *camera lucida* is a four-sided glass prism, set in a brass frame with a short tube. It is used in this way: you must take off the cap of the eye-piece, and slip the tube of the camera upon the top of the eye-piece; arrange the microscope in a horizontal position, and look through the camera at a sheet of paper on the table on which you are working; the magnified image of the object on the stage of the microscope will appear as if it were on the paper below. With a finely-pointed pencil you then proceed to take its outline; do not be disappointed if you cannot see both the image and the pencil; persevere, and in a short time you will succeed in making your drawing. The *neutral tint glass reflector*, which is cheaper than the camera lucida, consists of a small piece of slightly coloured glass which fits on the top of the eye-piece; the microscope must be inclined, as before. With a little practice the draughtsman will be able to draw the outlines on the paper.

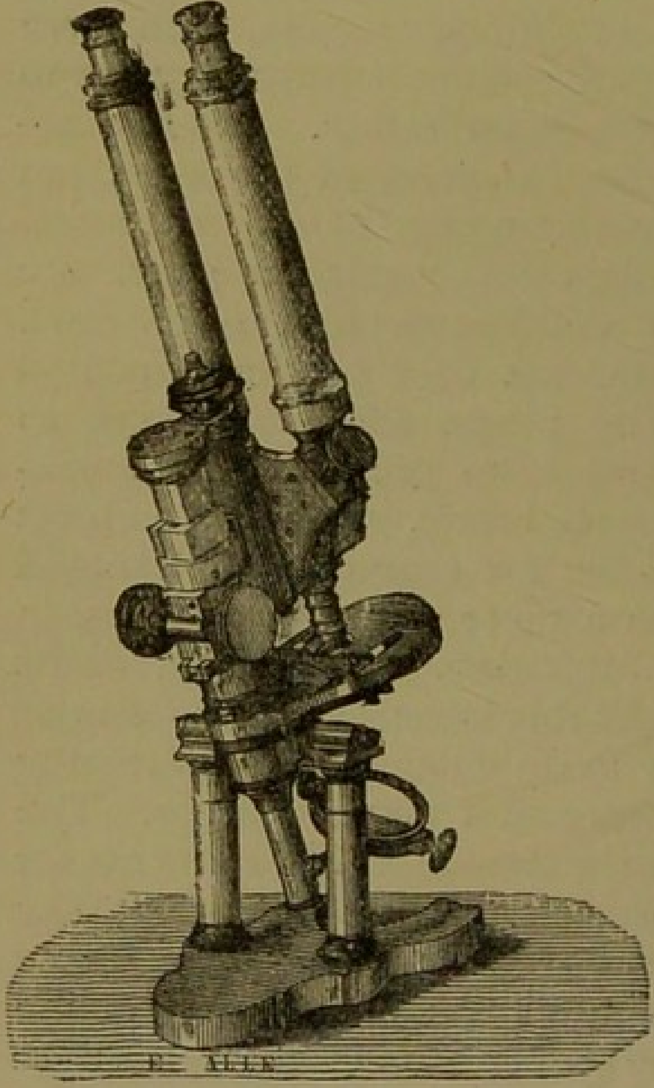
The polarising apparatus, by means of which various splendid colours are made to appear, is a luxury which the beginner may readily dispense with; though the effects produced, especially when a thin plate of selenite is interposed between the *analyser* and *polariser*, are often extremely beautiful; and though no doubt in some cases the internal structure of transparent objects is rendered very evident, yet for general microscopic work the polarising apparatus is not *necessary*.

Various lamps have been suggested as convenient forms for illumination. I do not think you need trouble yourself about a choice; a moderator or paraffin will serve your purpose well; only take care to use a lamp, and not candles, the constant flickering of which is trying to the eyes and irritating to the temper. You should provide yourself with the following necessary accessories to the microscope. (1) A number of plate-glass slides, three inches in length and one in breadth; they can be bought with the edges ground at about six shillings a gross. On these slides are to be placed the objects you may wish to examine, or to mount for preservation. (2) A quantity of thin glass of various degrees of thickness, cut in either square or circular pieces of different sizes. Thin sheets of this glass, called "cylinder glass," are manufactured by the well-known firm of Messrs. Chance, of Birmingham, but they can be procured at any optician's. The pieces should be kept in a box with bran or sawdust to prevent them breaking, for they are extremely brittle. When an object is placed on a glass slide for examination it should always be covered with a piece of this thin glass, in order to protect the object-glass from injury; whilst examining drops of water this is especially necessary.

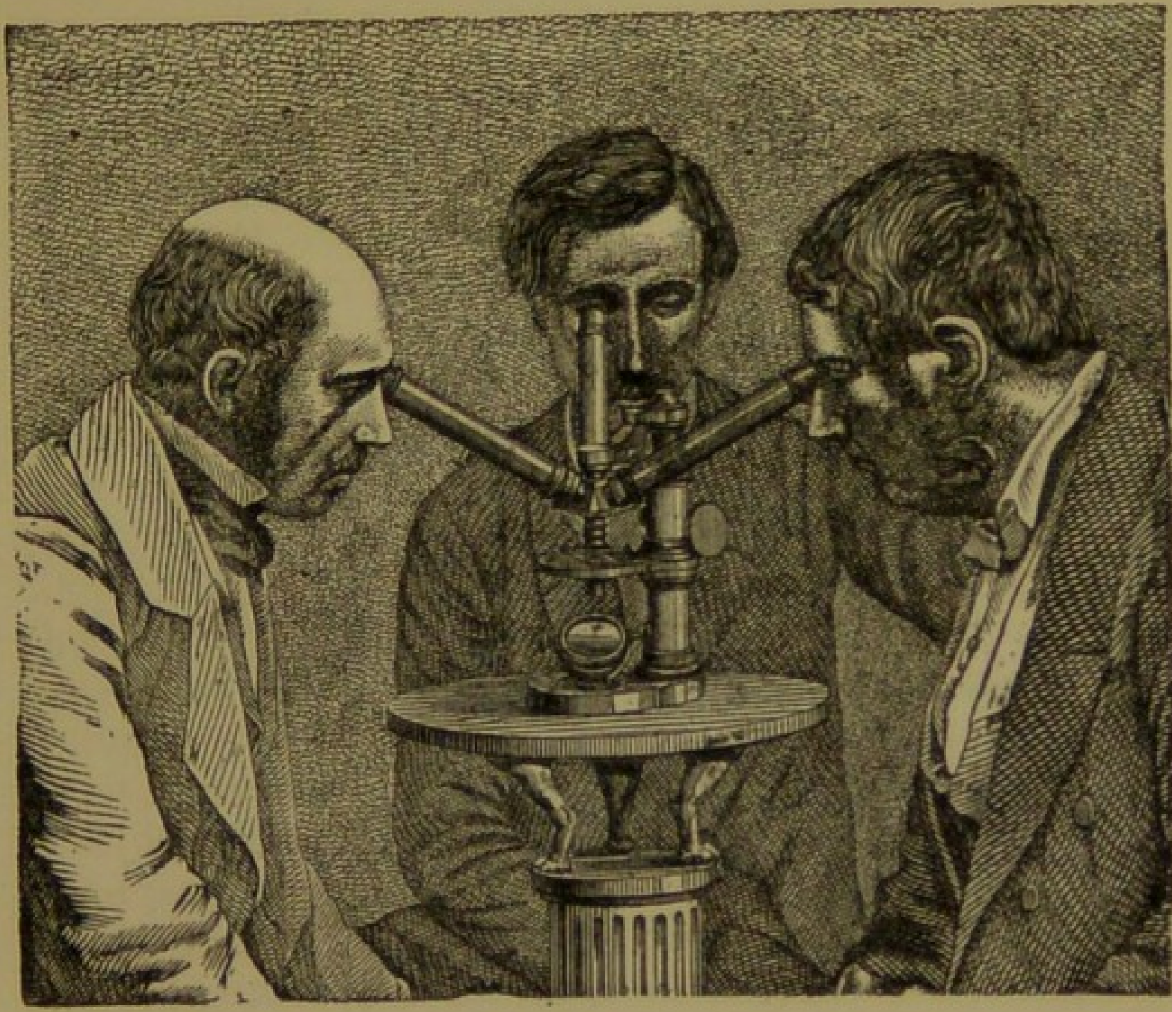
It would not be easy to do much work satisfactorily without dissecting-needles and a pair of forceps. The dissecting-needles are extremely useful instruments for unravelling entangled objects and various tissues; they can be readily improvised by the student taking some well-tempered needles, nipping off a portion of the heads, and inserting the upper part of the remainder in wooden handles. The forceps may be used independently, or be attached to the stage, for the purpose of holding minute objects under the microscope; its form will suggest to you various uses to which it may be applied.

A few watch-glasses will be found convenient for several purposes, and some small glass shades, about five inches in diameter, are useful for protecting from the dust objects you may be "mounting." I will make a few remarks on the "mounting" of microscopic objects in another chapter.

The microscope depicted in the adjoining woodcut represents one of Nachet's stereoscopic binoculars. The stereoscopic effect is produced by a peculiar arrangement of prisms. The binocular microscope, though it can hardly be regarded as necessary for the student, is very useful in the examination of opaque objects of solid form, and also of transparent objects, when we wish to ascertain the distinction between their nearer and more distant surfaces. The prolonged use of a binocular is attended with less fatigue than that of the monocular, and should you desire to procure one, Messrs. Beck and Beck, or Mr. Crouch, or Mr. Collins, or any other well-known maker, will supply you with an excellent one at the cost of about ten or twelve pounds. An ordinary monocular microscope can be converted into a stereoscopic binocular, should you desire it. The woodcut in page 15 represents three observers using one of the triple-bodied microscopes of M. Nachet.


A Binocular Microscope.

I will now give you a few short instructions in your use of the instrument. Let it be inclined at a convenient angle, screw on your low-power objective, and slide the eye-piece into the tube at the top of the body, having previously taken care to see the lenses are free from dust; place the object you wish to examine on a glass slide, and transfer it to the stage of the microscope; you will soon learn to obtain the proper focus. If your object is a transparent one, you must turn the mirror under the stage until a clear circular light illumines the field of view; if your object is opaque, you must use the condensing lens or the bull's-eye condenser, and throw the light *upon* the



Triple-bodied Microscope.

object. I should recommend you to practise yourself with the examination of objects that require low powers for some time before you try your hand on such as require high powers and very accurate and fine focussing. You will at first mistake small particles of dust, perhaps, for something connected with the object you are examining. In the examination of drops of water, numerous bubbles of air will present themselves in questionable shapes, and you will wonder what they are. In placing the thin glass over the drop of water, be careful to let its edge first touch the water, and then let it *slowly* fall on it. The surplus water should be wiped off, and care must be taken that the upper surface of the cover does not get wet, otherwise, if you are using a high power, you will get a misty view. Carelessly dropping or *flopping* the cover upon the drop of water is sure to produce air-bubbles, which may sometimes interfere most inopportunely and inconveniently with your getting a good view of the organ of some restless little animalcule. Never interfere with the lenses of the object-glasses; all that is necessary is to wipe the lower surface with a clean bit of wash-leather. Never leave the object-glasses uncovered when not in use, and never examine a drop of water without a thin glass cover over it. Do not touch the lenses of the object-glasses, or you will make them dim and misty. Attention to these instructions will repay you for your trouble, and save disappointment and probably expense.

CHAPTER II.

USE OF THE MICROSCOPE IN BOTANY.

It is almost impossible to exaggerate the value of the microscope in vegetable physiology, and the amount of information regarding the minute structure of plants which has been obtained by this instrument. You cannot, I think, do better than begin your microscopic studies with some of the various forms of plant-life that occur abundantly in our ponds, rivers, and ditches. Many of these are of very simple construction, and you may proceed from the investigation of a plant which has a separate existence as a single cell, to that of such complex and highly differentiated forms as the oak, the ash, and other mighty trees of the field or forest. Now the microscope will reveal to you the interesting fact that the origin of every plant is a single cell. Dr. Carpenter has well said, "The plan of organisation throughout the vegetable kingdom presents this remarkable feature of uniformity—that the fabric of the highest and most complicated plants consists of nothing else than an aggregation of the bodies termed cells, every one of which, among the lowest and simplest forms of vegetation, may maintain an independent existence, and may multiply itself almost indefinitely, so as to form vast assemblages of similar bodies. And the essential difference between the plans of structure in the two cases, lies in this : that the cells produced by the self-multiplication of the primordial cell of the protophyte, are all mere repetitions of it, and of one another, each living *by* and *for* itself; whilst those produced by the like self-multiplication of the primordial cell in the oak or palm, not only remain in mutual connection, but undergo a progressive 'differentiation;' a composite fabric being thereby developed, which is made up of a number of distinct organs (stems, leaves, roots, flowers, &c.), each of them characterised by specialities, not merely of external form, but of intimate structure (the ordinary type of the cell undergoing various modifications), and each performing actions peculiar to itself which contribute to the life of the plant *as a whole.* Hence, as was first definitely stated by Schleiden, it is in *the life-history of the individual cell* that we find the true basis of vegetable life in general."* What a marvel for contemplation, this vegetable cell, this living atom, endowed with such extraordinary and diversified power of reproduction !

The cells, as Pouchet observes, "represent little microscopic vesicles, at first globular, but which by increase and mutual compression become many-sided. And these elements, which conceal themselves from our eyes, animated by an inconceivable plastic force, and multiplying at a prodigious rate, cause new worlds to arise. 'Give me a lever and a fulcrum,' said Archimedes, 'and I will lift the globe.' M. Raspail, almost paraphrasing the geometer of Syracuse, was able to say, 'Give me a living cellule, and I will reproduce all creation.'"

You can readily make yourself acquainted with the form of a simple cell and its growth, by placing a very small quantity of fresh yeast under the microscope, with a power of 400 diameters. The whole substance seems to be nothing but an aggregation of these minute cells. Look at them; each is like a little

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* "The Microscope," p. 241. Fourth Edition.

globe, and—like most vegetable cells—consists of a membranous bag with some fluid contents. The vegetable cell-wall is generally composed of two layers having different properties and composition. They are excessively thin, and difficult of detection, unless you add iodine or other colouring matter. The inner layer, which can only be separated from the outer one "by developmental changes, or by the influence of re-agents which cause it to contract by drawing forth part of its contents," is called the *primordial utricle*, as "being first formed and most essential to the existence of the cell." The outer cell is supposed to be merely a protective covering; the contents of the cell consist of colourless protoplasm (organisable fluid), containing albuminous matter in combination with starch, gum, sap, and a green, oily substance called *chlorophyl*. But let us return to the yeast cells. They are still of the same form as when we looked at them before, and independent of each other. I will add a little newly-made beer, or some albuminous matter mixed with sugar, and what do we see after the interval of a few hours? No longer single unconnected globules, but a number together forming chains. Each cell has budded out one or two little projections, which have developed themselves into complete cells, in their turn giving origin to fresh ones, and so on continuously as long as the fermenting process continues. When this is stopped, the yeast-plant —it is a fungus called *Torula cerevisiæ*—returns to its isolated condition once more. In quoting an extract from Dr. Carpenter, I mentioned the term *protophyte*.* The yeast fungus is a good example of organisms designated by this word, which, as its derivation shows, is intended to define the most simple, primi-

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* From πρῶτος, "first," and φυτὸν, "a plant."

tive, and elementary forms of vegetation. Vegetable cells are of various shapes and sizes; they may be globular (Fig. 1), or square, hexagonal (Fig. 2), cydrical (Fig. 3), spindle-shaped, &c. &c. Sometimes the cell-walls grow unequally at different points, so as to produce angular projections by which the cells cohere; or they grow out into long arms, thus producing stellate cells, as in the pith of the rush, a thin section of which, when viewed by reflected light, is a very pretty microscopic object. Thin sections of any soft vegetable tissues are readily made with a razor or very sharp knife. Starch is found abundantly in the cells of a great many vegetables. The granules vary much in form and size, and are generally so characteristic of the plants, that it is an easy matter to detect, by means of the microscope, adulterations in food. Fig. 4 represents a thin section of a potato, showing the cells and starch-granules con-

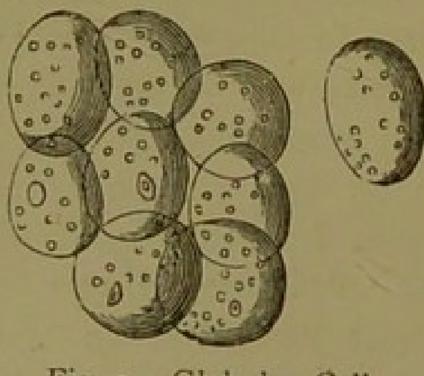

Fig. 1.—Globular Cells.

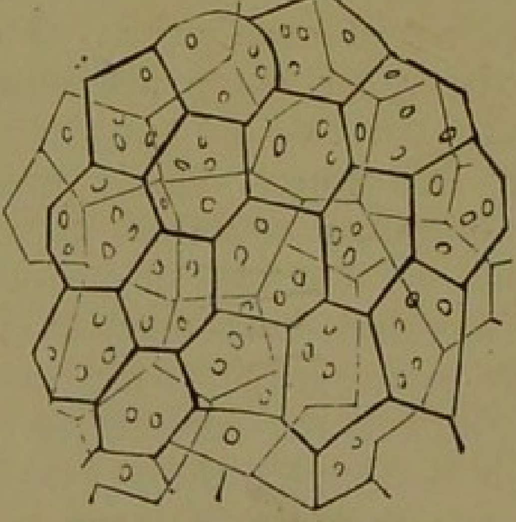

Fig. 2.—Hexagonal Cells.

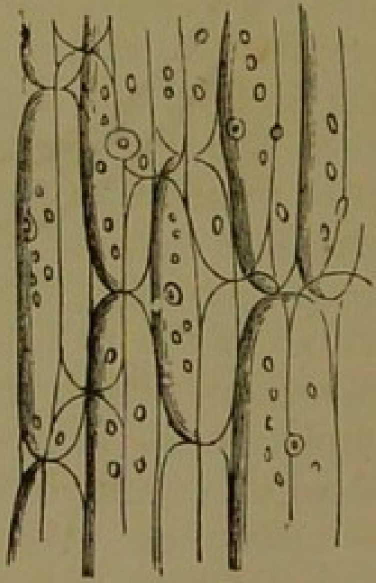

Fig. 3.—Cylindrical Cells.

tained therein. Starch is the most generally diffused substance, except protoplasm,* met with in vegetable cells; it occurs in all classes of plants, except funguses. It can always be detected by the application of iodine, which immediately turns the granules blue. I should recommend you to make yourself acquainted with various forms of starch-granules of several common plants, such as wheat, rice, Indian corn, and arrow-root. It is supposed by some microscopists that the structure of a starch-granule is composed of a series of concentric shells or layers, which are firm as they approach the outside wall, but are less dense and more full of water as they approach the centre or nucleus. The granules may be isolated from the cells by macerating slices in water for a few days.

Fig. 4.—Section of Potato, showing Cells and Starch Granules.

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* The name is applied to the nearly colourless granular viscid substance, nitrogenous in nature, which constitutes the formative matter in the cells. From πρῶτος and πλάσμα, "form."

One of the largest forms of starch-granules is that of *tous-les-mois* (*Canna*).

The circulating movement of particles in the cells of certain plants is an extremely interesting sight, and in some can be observed without much difficulty. Those generally selected for exhibiting this phenomenon are *Chara nitella* and the American weed *Anacharis alsinastrum*. The long ribbon-like leaves of *Vallisneria spiralis*—a plant not indigenous in this country, but which may be purchased in Covent Garden and elsewhere—show this *cyclosis*, or circulatory movement, of chlorophyl particles admirably. You must take a very thin strip or layer from the surface of a young leaf, using a sharp knife; place this upon a glass slide with a drop of water, and cover it with very thin glass, using a power of 300 or 400 diameters. The circulating corpuscles will be seen to traverse the cell-walls round and round. Should the circulation stop, you should submit the strip to gentle heat, when it will go on again. The hairs of certain plants exhibit the same phenomenon, such as those of *Tradescantia Virginica*, the Virginian spider-wort; *Anchusa paniculata*, one of the borage family; the young hairs of the nettle show the same rotation under a very high power. Crystals, or *raphides* as they are termed, are found in many plants, and are interesting microscopic objects. The name "raphides," from the Greek word *raphis*, "a needle," was first applied to crystals having a needle-like form; but it is now used in a general sense to express any crystalline formation. These bodies are found usually within the cells in almost any part of the plant—in the stem, leaves, bark, or pith. In the bulbs of the lily tribe they occur extensively. You can readily see them in the cuticle of the common onion; strip off a small piece, and view it with a power of about 200 diameters, and you will notice some very pretty groups of octohedral or prismatic crystals. They are generally composed of oxalate of lime, or of carbonate, sulphate, and phosphate of lime. Dr. Carpenter says that "certain plants of the *cactus* tribe, when aged, have their tissue so loaded with *raphides* as to become quite brittle, so that when some large specimens of *C. senilis*, said to be a thousand years old, were sent to the Kew Gardens from South America, some years since, it was found necessary for their preservation during transport to pack them in cotton like jewellery."* What office these crystalline bodies fulfil, or whether they fulfil any at all, is not known. Raphides have been artificially produced within the cells of rice-paper. Mr. Quekett filled the cells with lime-water by means of an air-pump, and placed the paper in weak solutions of oxalic and phosphoric acids. "The artificial raphides of phosphate of lime were rhombohedral; while those of oxalate of lime were stellate, exactly resembling the natural raphides of the rhubarb."

The spiral vessels of plants will amply repay you for investigation by their extreme beauty: they are easily seen by macerating the stems or leaves in water, or by boiling them. These spiral vessels are cylindrical tubes with cone-like ends, within which fibres wind in a corkscrew fashion. In some cases the tube contains only one spiral fibre; in others as many as twenty have been counted (Fig. 5). These vessels are found in all parts of plants excepting the roots. They are very beautiful in the seeds of certain plants, as in the strawberry and hazel-nut. Every one is familiar with the brown coating that surrounds the common nut; scrape a portion of this membrane off the kernel, and

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* "The Microscope," p. 400.

soak it in water for a time; tear it in pieces with a pair of needles, and examine under the microscope with reflected light, you will see a great number of glistening fibres. It seems probable that the use of these spiral vessels is to convey air to the plants, thus forming a system of internal respiration, which at once suggests an analogy to that of insects, the tracheæ of which very closely resemble the spiral vessels in the vegetable kingdom. Spiral vessels, however, are sometimes found to convey fluid. The various kinds of ducts, or the canals through which fluids are carried to different parts of plants, will form objects for study; spiral, annular, dotted, scalariform, and reticulated ducts are interesting varieties of form.

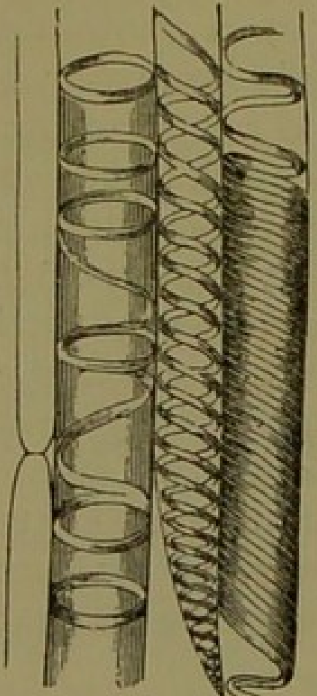

Fig. 5.—Spiral Vessels.

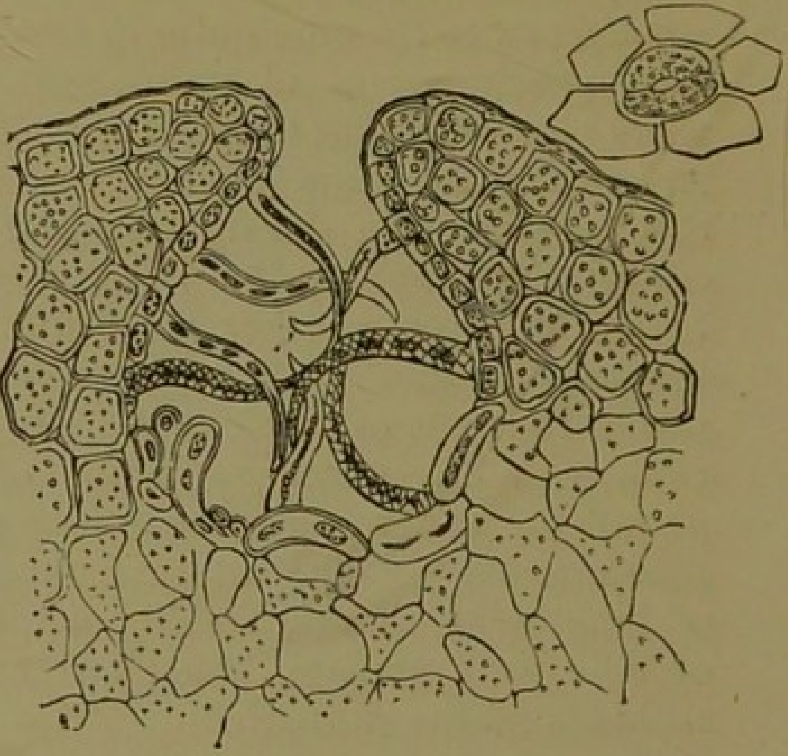

Fig. 6.

Among other important organs, the *stomata*, or little openings by which almost all leaves with distinct cuticles are perforated, must be mentioned. These organs are really mouths through which respiration and exhalation are carried on in plants; they lead into cavities beneath the epidermis. The usual form of the stomata consists of a number of rounded cells, bordering the opening, with a couple of kidney-shaped cells of a large size in the centre; between these is a narrow slit when the mouth is open, and a raised seam when it is shut. In some plants the stomata do not open on the surface of the leaf, but lie in depressions in it; these are lined and guarded with a number of hairs, as in the oleander (see Fig. 6). You would do well to make yourself acquainted not only with the function, but the various forms of the stomata. The examination of their structure is easy. Take a leaf or flower of almost any plant, tear a thin slice off its under surface, put it in a glass slide with a drop of water, cover it with thin glass, and use a power of about 200 diameters. Examine the outer surface of the object first; then you will see the cells and slit of which I spoke. Now examine the other side, and notice the cavity into which the slit is directed. Stomata are usually more abundant on the lower surface of leaves; but in plants whose leaves float on the water they are found only on the upper surface, as in the water-lilies; in plants whose leaves are always submerged there are no stomata; in grasses and such plants as grow in an erect form they are found on both surfaces equally distributed. As many as 160,000 of these little mouths have been counted on each square inch of surface on leaves of some plants. In the liverworts, as in *Marchantia polymorpha*, the stomata are of very complex structure. These organs are not found in the roots of plants, nor in the ribs of the leaves; and they are absent from fungi, lichens, and sea-weeds.

The study of hairs, which are so abundant on many plants, will afford you much pleasure and instruction, so variously formed and beautifully constructed as the microscope shows them to be; they are generally attached to the cuticle by one end, having the other one free. To the naked eye the hair of the *Tradescantia Virginica*, for instance, looks like a single thread-like process; under the microscope it is found to consist of three or four successive cells. I ought to say that vegetable hairs are always of a cellular character. Some hairs appear to be attached to the epidermis by their centre portion, and assume very pretty stellate or starlike forms. Such cases are, no doubt, merely clusters of hairs each attached by its lower extremity. Fig. 7 represents the sinuous cells and starlike hairs of the leaf of the *Deutzia scabra*, a very beautiful and favourite microscopic object. These hairs are covered with a siliceous coating, and when viewed by reflected light shine with great brilliancy. Hairs may consist of single cells, or of numerous ones arranged one above the other, or they may be branched, or toothed, or plumose; indeed their forms are almost unlimited. In some hairs you may see a single cell which contains an elastic coiled-up spiral fibre. Hairs may be, as we all know by experience, either harmless to touch, or hurtful. The hair of the common nettle contains at the base a poisonous fluid, which is conveyed into the wound through a

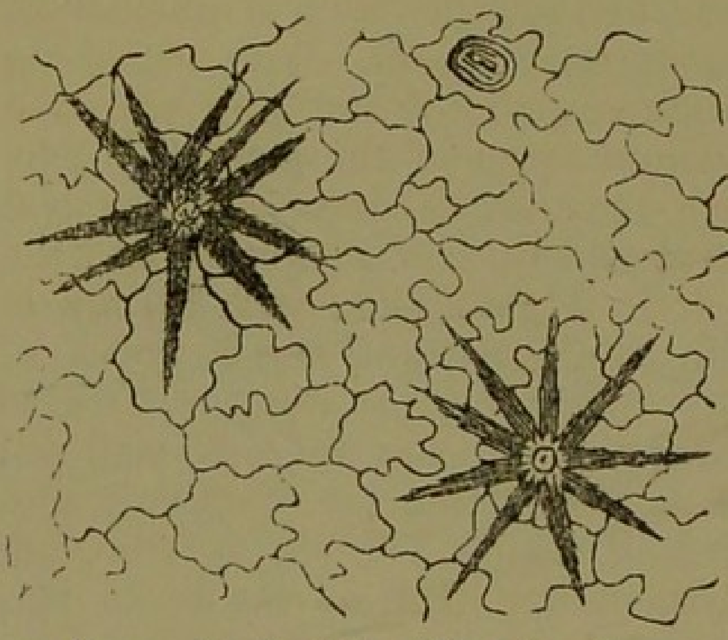

Fig. 7.—Starlike hairs of Deutzia scabra.

duct ending at its finely-pointed extremity. We are here reminded of the analogous case of a viper's tooth in the animal kingdom. The phenomenon of *cyclosis*, of which I have already spoken, takes place probably in all kinds of hairs. Mr. Wenham says, "The difficulty is to find exceptions, for hairs taken alike from the loftiest elm of the forest, to the humblest weed that we trample beneath our feet, plainly exhibit this circulation." To witness it, however, very high powers of the microscope and great care are necessary. In your examination of hairs, remember to tear off a part of the cuticle from which they grow. If you take hold of the hair itself, it will be almost sure to break; place the piece in a drop of water, with a thin glass covering, and the forms of the various kinds will reveal themselves.

CHAPTER III.

USE OF THE MICROSCOPE IN BOTANY—(*continued*).

YOU will, no doubt, be much interested in examining the structure of the hard portions of plants, such as the stems, roots, seeds, &c. In many cases you will find a sharp knife or razor sufficient for making sections of the parts you wish to study; such substances as the stony fruits of various trees require a more expensive apparatus in order to prepare them for investigation. I shall therefore take no notice of these hard substances at present. You must take care to prepare the stems or roots before you make your sections; if the wood be green, you must soak it for some days in strong spirit, in order to get rid of any resinous matter it may contain. After this, let the specimen be macerated in water for a few days; this will remove the gum. If the portion of wood you wish to study be dry, you must moisten it in water for some time to soften it, then treat it as you would green wood. It may be necessary in some cases to use boiling water to render the stems sufficiently soft for making sections. Wet the surface of the wood, and cut off as thin a transverse section as possible. Instruments called "section instruments" are sold for this purpose, and very handy and useful some of them are; you can add one to your microscopic apparatus after you have had more experience; but you will find that, with care and perseverance, you will succeed in making very thin sections of stems, which will show their different parts, such as the pith, medullary rays, bundles of wood and bark, quite satisfactorily. In the examination of the reproductive organs of plants, you will find exhaustless matter for study and contemplation. Every one is familiar with the dusty particles contained within the stamens of different plants, called pollen (Fig. 8). Various and very beautiful are these pollen forms, and easy enough to examine, so far as the external appearance goes. Perhaps their most common form is spherical or elliptical; but many beautiful geometrical forms are met with, such as cubic, tetrahedral, polygonal, &c. In structure, the pollen grain generally consists of an internal cell membrane, with one or more outer layers of firmer texture. In some instances, as in the *Zostera marina*, there is only an inner membrane. The outer covering may be smooth, or rough with numerous spiny projections, or reticulated, or divided into several segments or bands, or beset with numerous pores

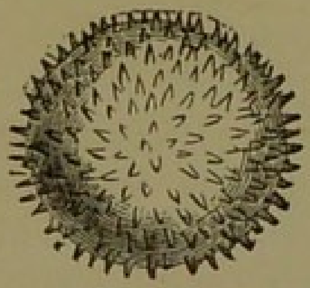

Fig. 8.—Pollen Grain.

regularly or irregularly scattered. Pollen grains are developed in the stamens (Figs. 10 and 11), which are the pollen-cases; when they have arrived at maturity, that stage at which they are fitted for the purpose of fertilisation, the pollen-cases burst, and clouds of pollen are shot forth like dust. Have you not often dusted your nose with the yellow pollen of the garden *Eschscholtzia?* You have also, I dare say, been often struck with the astonishing quantity of pollen sometimes found on a single stamen. A very little is absolutely required for the fertilisation of the pistil: why, therefore, this extraordinary abundance? A great deal of pollen, as you may suppose, runs to waste. Such is the structure and position of the pistils of many plants, that contact of the pollen-grains with the ovule is often impossible except for the agency of the winds, or of various birds and insects. The internal cell contains a fluid (*fovilla*) which is supposed to

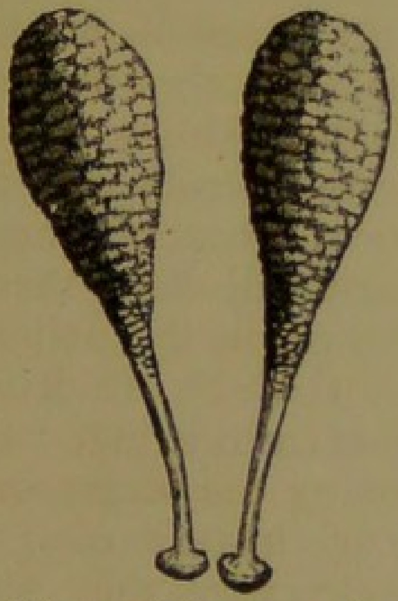
Fig. 9.—Pollen mass of Orchis Maculata.

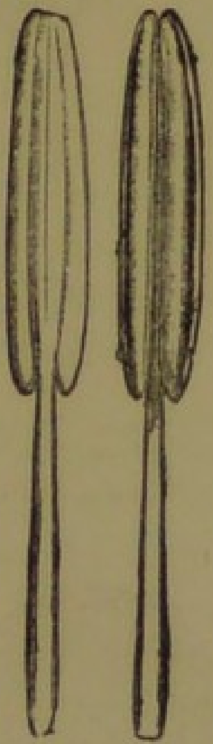
Fig. 10.—Stamens of Iris.

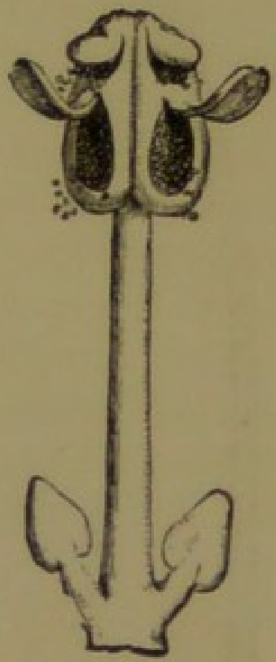
Fig. 11.—Four-celled Anther of Persian Laurel.

be the fructifying substance. The development of the pollen-grain after it has touched the soft viscid tissue of the pistil is very remarkable; one or more little processes bud out of the grain (Fig. 13); in time this tube or process becomes much elongated (Fig. 14); it insinuates itself between the cells of the stigma, until, continually elongating itself, it arrives at the ovule at the bottom of the ovaries which are thus fertilised by it. The illustrations here given will show these changes in the pollen-grain which we have been considering. "In tracing the origin and early history of the ovule, very thin sections should be made through the flower-bud, both vertically and transversely; but when the ovule is large and distinct enough to be separately examined, it should be placed on the thumb-nail of the left hand, and very thin sections made with a sharp razor; the ovule should not be allowed to dry up, and the section should be removed from the blade of the razor by a wetted camel-hair pencil. The tracing downwards the pollen tubes through the tissue of the style may be

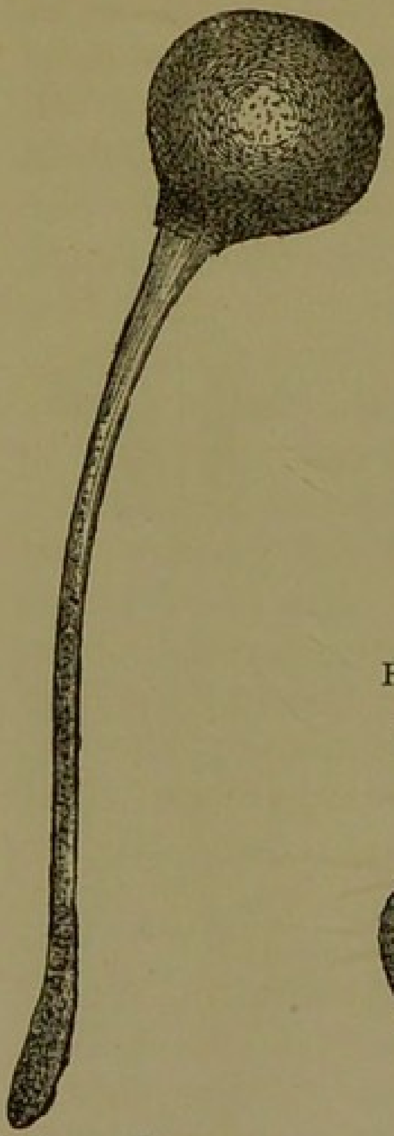
Fig. 14.


Fig. 12.—Stamen ejecting its Pollen-grains.

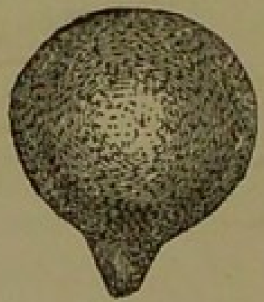
Fig. 13.

accomplished by sections (which, however, will seldom follow one tube continuously for any great part of its length), or, in some instances, by careful dissection with needles. Plants of the orchis tribe are the most favourable subjects for this kind of investigation, which is best carried on by artificially applying the pollen to the stigma of several flowers, and then examining one or more of the styles daily. 'If the style of flower of an *Epipactis* (says Schacht), to which the pollen has been applied about eight days previously, be examined in the manner above mentioned, the observer will be surprised at the extraordinary number of pollen-tubes, and he will easily be able to trace them in large strings, even as far as the ovules. *Viola tricolor* (heart's-ease) and *Ribes nigrum* and *rubrum* (black and red currant) are also good plants for the purpose; in the case of the former plant, withered flowers may be taken, and branched pollen-tubes will not unfrequently be met with.' The entrance of the pollen-tube into the micropyle* may be most easily observed in *orchideous* plants and in *Euphrasia;* it being only necessary to tear open with a needle the ovary of a flower which is just withering, and to detach from the placenta the ovules, almost every one of which will be found to have a pollen-tube sticking in its micropyle. These ovules, however, are too small to allow of sections being made, whereby the origin of the embryo may be discerned; and for this purpose, *Œnothera* (evening primrose) has been had recourse to by Hoffmeister, whilst Schacht recommends *Lathræa squamaria*, *Pedicularis palustris*, and particularly *Pedicularis sylvatica*."†

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* From μικρός, "small," and πύλη, "a gate," the minute perforation through the skin of a seed.

† Dr. Carpenter on the Microscope, p. 430.

You will find much to attract your attention and excite your admiration in some of the lowest forms of vegetation. The lichens, mosses, sea-weeds, fungi, will all demand your notice, and none will fail to repay you for the pains of a careful investigation. Some of the fresh-water algæ are extremely beautiful and readily procurable, whilst, should you pay a visit to the sea-side, the "flowers of the sea" when gathered, in some form or other, on every shore, will supply a wide field for investigation. The common *Fucus vesiculosus*, whose ovoid capsules you explode at almost every tread of the foot; or the nearly equally common *F. platycarpus* will amply repay you for careful research. You will notice the receptacles at the extremity of the fronds; in the group of Fuci there is no doubt about a true sexual mode of fructification

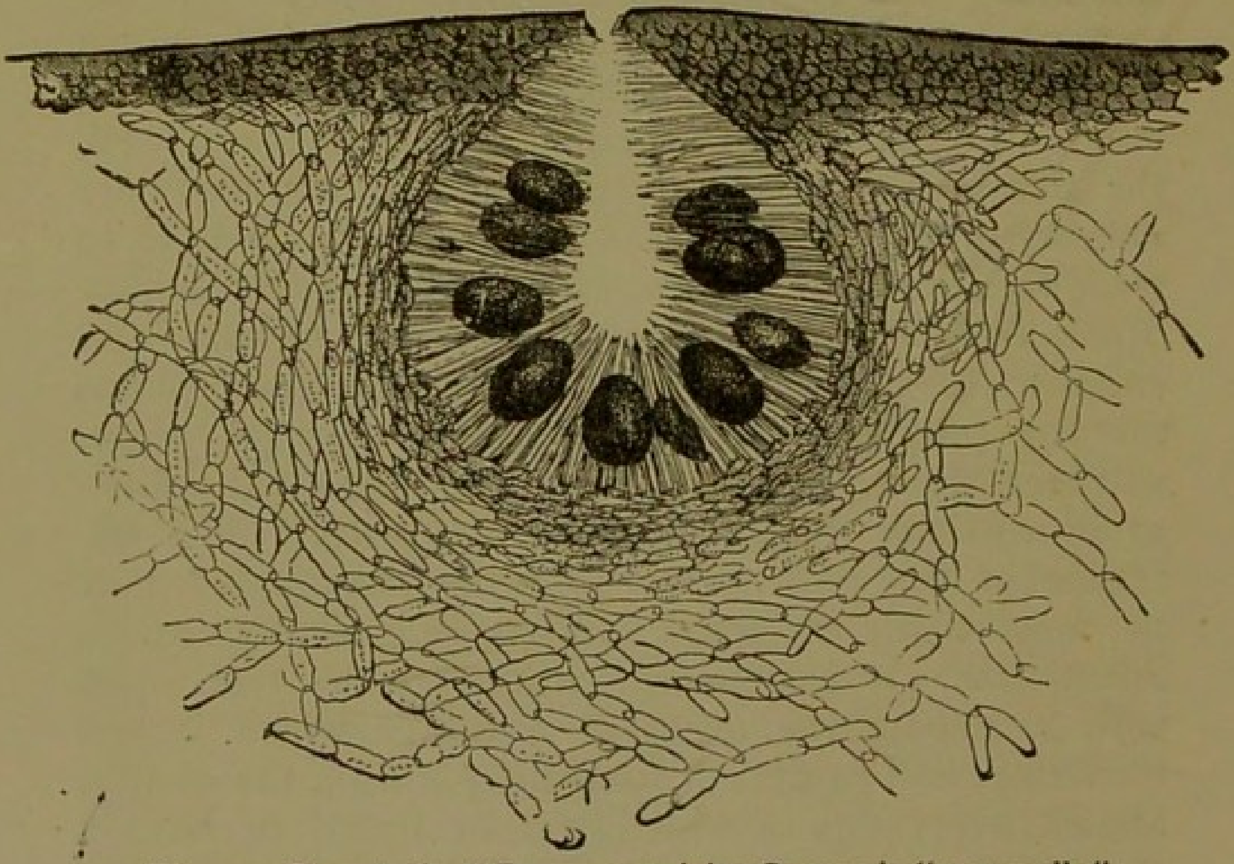

Fig. 15.—Receptacle of Fucus, containing Sporangia "germ-cells."

(Fig. 15). The fungi, again, will demand your attention; the minute reproductive bodies thrown off from the gills of the Agaric group in countless millions, known by the name of "spores," will interest you much. Gather a common mushroom or other fungus, cut off the stem near the gills, place it with the gills downwards on a sheet of paper, black or white; leave it in this position for several hours; on taking it up you will notice the gills have deposited a quantity of dust-like stuff upon the surface of the paper. The colour varies according to the families to which the fungi respectively belong; in the mushroom the "spores" are pink, in some fungi they are rust-coloured, in others white, in others black. Just notice how beautifully the deposited spores represent the form of the gills, then scrape a portion off the paper, and submit it to microscopic examination. Bear in mind this distinctive difference between a "seed" and a "spore"—a seed contains an embryo, a spore has none.

The little brown patches on the under side of some of the ferns will attract your attention; these are the spore-cases of different forms, and variously disposed according to the genus of plant on which they occur. The spore-case, in some genus of ferns, is surrounded by a curious elastic band, which, when the spores contained within are ripe, suddenly jerks itself straight, tears open the case, and disperses the minute spores in all directions. You can witness the germination of fern-spores by placing some on a damp surface, and exposing them to light and heat. At first each one puts forth a tubular prolongation; the cells of the spore multiplying by subdivision both transversely and longitudinally, give rise to a flattened leaf-like expansion, which from its under surface developes both root-fibres and reproductive organs. Every one is acquainted with those curious-looking plants called horsetails (*Equisetaceæ*); you will find them interesting microscopic studies. Take hold of one; you notice how rough it is; this roughness is caused by a quantity of silex which permeates the whole of the structure of the horsetail. To such an extent does this in some cases take place, that "even when its organic portion has been destroyed by prolonged maceration in dilute nitric acid, a consistent skeleton still remains." These horsetails are reproduced from spores on a spike at the end of some of the branches. To each spore are attached two pairs of elastic filaments; at first they are coiled up round the body of the spore; at the liberation of the spore they extend themselves. "If a number of the spores be spread on a slip of glass under the field of view, and whilst the observer watches them a bystander breathes gently upon the glass, all the filaments will be instantaneously put in motion, thus presenting an extremely curious spectacle, and will almost as suddenly return to their previous condition when the effect of the moisture has passed off."* I have frequently witnessed this curious spectacle, and you can easily do so yourself by following Dr. Carpenter's directions, which I have just quoted. The *Equisetaceæ* develop themselves from these spores after the manner of ferns; on this account the name "fern allies" has been applied to their family.

You will find endless variety of form and markings in the seeds of plants. Seeds as microscopic objects under a low power and by reflected light, or viewed under the binocular, are often extremely beautiful. Take the seed of the poppy; notice the network markings upon its surface; or the seed of the carrot with its long starfish-like radiating processes. Make

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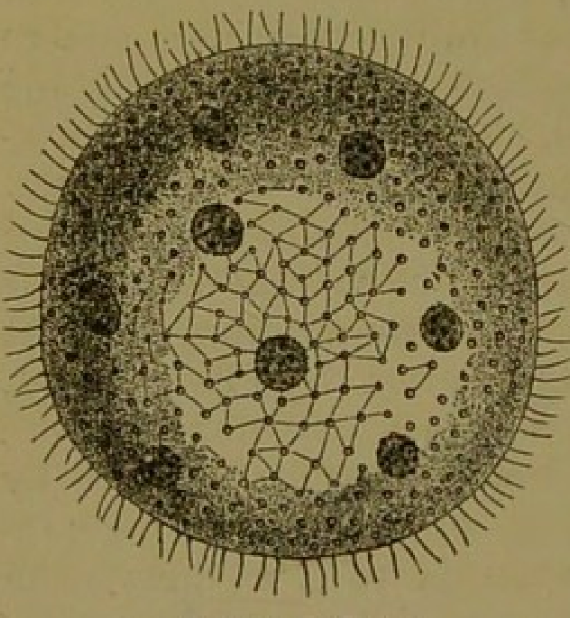
* Carpenter, p. 383.

a transverse section of any seed, you will find it has two coats, an outer and inner membrane called respectively *testa* and *tegmen;* you will see the embryo either surrounded by albumen or immediately invested by the coats. The following easily procured plants will furnish you with samples of seed-forms: poppy, stitchwort, mignonette, snapdragon, saxifrage, sweet-william, foxglove. You can add to this list almost indefinitely.

Every stream, ditch, and pond will supply you with many forms of algæ, known as *Diatomaceæ* and *Desmidiaceæ.* Once these organisms were supposed to belong to the animal kingdom, on account of some of them exhibiting motion; there is no doubt, however, that both these families are true vegetables. They are found in masses of jelly-like substance attached to the stems or leaves of various aquatic or marine plants, or they envelop any submerged plant with loose brownish flocculent matter. The *Diatomaceæ*, or brittleworts, are invested with a covering of silex; this fact you can readily demonstrate for yourself by boiling the minute plants in nitric acid, having previously washed them well, so as to free them from extraneous matters. The organic vegetable matter is destroyed; the siliceous portion remains. The *Desmidiaceæ*, another family of confervoid algæ, are destitute of any siliceous covering; they are generally of a green colour, and are found, like the *Diatomaceæ*, investing submerged plants or other bodies. These microscopic algæ, under a power of 300 to 400 diameters, are very striking objects; they come "in such questionable shapes" that you cannot help but "speak to them." Now circular, now filamentary, beautifully jointed, now like small boats in outline, now crescent-shaped—in fact, every variety of form exhibiting—these algæ, I have no doubt, will occupy much of your time. And here I should wish to give you some advice which you will find useful as a beginner. It is well *at first* to make yourself acquainted with various forms of plant-life—to run cursorily at first, but mind, *only at first*, over various objects. You will thus gain a sort of general notion of the interesting field of operations before you. Real special work—and I hope you are going in for real work—must begin after you have made a general survey of the land in which you wish to make conquests. It is not well for a beginner to embark all at once, without some general knowledge of the field of labour, into special work.



Volvox Globator.

All these plants, you will see, evolve oxygen when exposed to the light of the sun; those bubbles which bespangle that brown-coated stem from the confervæ are bubbles of oxygen, which at once disclose, even in the absence of further proof, their vegetable nature. Many other forms of undoubted vegetable nature which have been, at one time or another, claimed by the zoologists as belonging to the animal kingdom, might be enumerated. Prominently we may notice that curious protophyte not uncommon in stagnant water, called *Volvox globator*. Look out for specimens in the spring and summer months; they are easily seen where they abound, about the size of a small pin's head, and of a greenish colour: they will attract your eye when they roll along in the glass bottle in which you have collected some specimens. I have generally found *Volvox globator* in stagnant ponds containing a profusion of aquatic vegetation. The ordinary size is about $\frac{1}{30}$ of an inch in diameter. "When examined with a sufficient magnifying power, the volvox is seen to consist of a hollow sphere, composed of a very pellucid material, which is studded at regular intervals with minute green spots, and which is often, but not constantly, traversed by green threads connecting these spots together. From each of the spots proceed two long *cilia;* so that the entire surface is beset with these vibratile filaments, to whose combined action its movements are due. Within the external sphere may generally be seen from two to twenty other globules of a darker colour and of varying sizes; the smaller of these are attached to the inner surface of the investing sphere, and project into its cavity; but the larger lie freely within the cavity, and may often be observed to revolve by the agency of their own ciliary filaments. After a time the original sphere bursts, and the contained spherules swim forth, and speedily develop themselves into the likeness of that within which they have been evolved." When you see, as you will do, various organisms swimming freely about in a drop of water, you will be inclined to put them down as belonging to the animal kingdom. Suspend your judgment; it is quite probable what you see are motile cells of certain vegetable organisms. What is the difference between a plant and an animal?

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* Carpenter, "Microscope," p. 251.

CHAPTER IV.

USE OF THE MICROSCOPE IN ZOOLOGY.

In the last chapter I asked the question, "What is the difference between a plant and an animal?"—a question more easily asked than satisfactorily answered, for when we examine very low organisms, we seem to touch the confines of the two kingdoms; but these confines are very difficult to determine—indeed, some scientific men have denied any absolute distinction between the two kingdoms. They assert that, notwithstanding the manifold differences in form and structure, there is a "physical basis of life underlying all the diversities of vital existence;" that "a threefold unity—namely, a unity of power or faculty, a unity of form, and a unity of substantial composition—does pervade the whole living world." According to that eminent biologist, Professor Huxley, the formal basis of all life is protoplasm, simple or nucleated; and in the lowest plants, as in the lowest animals, a single mass of such protoplasm may constitute the whole plant, or the protoplasm may exist without a nucleus. How, then, it is asked, is one mass of non-nucleated protoplasm to be distinguished from another? Why call one plant and the other animal? The only reply is that, so far as form is concerned, plants and animals are not separable, and that in many cases it is a mere matter of convention whether we call a given organism an animal or a plant. There is a living body called *Æthalium septicum*, which appears upon decaying vegetable substances, and in one of its forms is common upon the surfaces of tan-pits. In this condition, it is to all intents and purposes a fungus, and formerly was always regarded as such; but the remarkable investigations of De Bary* have shown that in another condition the *Æthalium* is an actively locomotive creature, and takes in solid matters, upon which apparently it feeds, thus exhibiting the most characteristic feature of animality. Is this a plant, or is it an animal? Is it both; is it neither? Some decide in favour of the last supposition, and establish an intermediate kingdom, a sort of biological No Man's Land, for all these questionable forms. But as it is admittedly impossible to draw any distinct boundary line between this No Man's Land and the vegetable world on the one hand, or the animal on the other, it appears to be that this proceeding merely doubles the difficulty, which before was single.†

Notwithstanding, however, the great difficulty, if not impossibility, of drawing a distinction between some of the lowest forms of the animal and vegetable kingdoms, as a general rule the boundaries are sufficiently distinct. I have called your attention to the remarks of Professor Huxley on this subject, in order that you may see what great problems the microscope helps to solve. I will now direct you to a consideration of some of the minute forms of undoubted animal life which every pond or ditch contains in endless variety and profusion. Of so-called monads—extremely minute organisms found in water containing decomposed vegetable or animal matter, several supposed species of which have been described—I need say but little. There can be no doubt, notwithstanding the opinion of Ehrenberg, that the *Monadina* family con-

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* "Die Mycetozoen." Leipzig, 1864; also an abstract in Hoffmeister's "New System of Botany."

† "On the Physical Basis of Life."—*Fortnightly Review*, Feb., 1869.

sists of a heterogeneous group, some forms of which may be the zoospores of algæ, others the germs of animalcules. The *Monadina*, which quite recently have been regarded as the most minute living creatures discovered, comprising several distinct genera—such as *Monas*, *Euglena*, *Uvella*, *Syncrypta*, *Chlamydomonas*, *Bodo*, and many more—can no longer stand as a family representing different mature animal forms.

For obtaining microscopic objects from the pond, stream, or ditch, all you want is a wide-mouthed bottle or two, a bit of wire, a walking-stick, a lens, and a canvas or strong muslin net. A cutting hook to screw into the end of your walking-stick will be useful in nipping off the stems of aquatic plants, which always harbour many forms of animal life. Several kinds of animalcules, wholly invisible to the unaided eye as single objects, are discernible as groups ; among which I may mention to you the green masses of *Ophrydium versatile*, and various *Vorticellæ*, which may be frequently seen encircling submerged stems or other bodies with a dirty-white flocculent mass. *Ophrydium versatile* lives in societies of many thousands together, in balls of a whitish jelly-like substance. The colour of the animalcules is green, and this gives the colour to the masses of jelly in which they live. The size of these balls varies from that of a pea to that of a man's fist. In form each individual is very like a Stentor, especially when it is free—for these little creatures can leave the jelly-like ball, and swim freely in the surrounding fluid—but as long as an *ophrydium* is an inmate of the jelly ball, it possesses, at the hinder end, a very long thread-like tail, much longer than itself; this tail seems to anchor the animalcule securely in the gelatinous substance. You may meet with these balls in clear water in the spring and early summer months.

The little creatures called *Stentors* are very interesting to study. Each one looks like a miniature green trumpet, and is visible to the unassisted eye. Look carefully at the engraving: you notice that the goblet-shaped mouth is surrounded with a circle of hairs; these are called *cilia*, from the Latin word meaning eyelashes, a designation appropriate enough. There are many curious forms of these *ciliated* protozoa, and it will be a source of much pleasure to you to make their acquaintance from time to time. The whole body of the *stentor* is, as you observe, covered with cilia—organs which play a very useful and prominent part in these creatures' lives. They serve both for the purposes of progression—for by these numerous hairs the animalcules row themselves about with wonderful rapidity—and also, when arranged in a circlet round the mouth, for obtaining food. The constant lashing of these cilia produces currents of water, which convey to the animalcule particles of food, whether of an animal or vegetable nature. These Stentors are of various colours—it is supposed there are many species of the genus; five or six have been described—either white, black, blue, or green; and like their relations, the Ophrydia, are capable of assuming various forms. They increase, like numerous other forms of low animal life, by self-division. Such splitting may take place either longitudinally or obliquely, and each part may form a perfect animal. You will often witness animalcules in the act of separating into

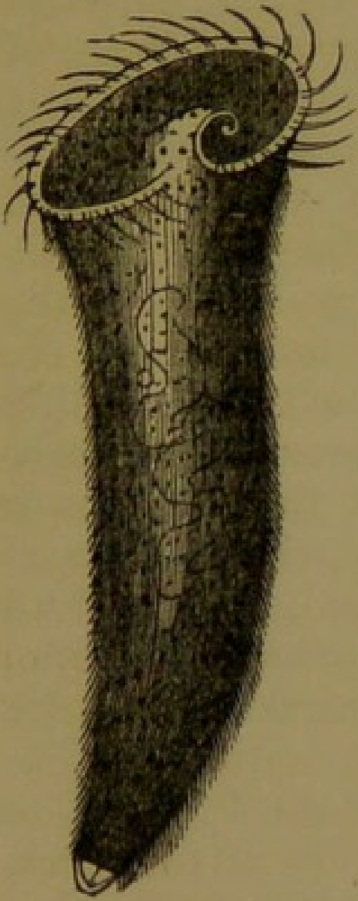


Fig. 16.—Stentor.

two portions; this method of reproduction is analogous to that of the budding of plants. But even in animals so small as, and even much smaller than, a Stentor, a true sexual reproduction takes place. It is to the researches of Balbiani that we are indebted for our knowledge of this most interesting fact. It seems pretty certain that, both in the case of animals and plants, a contact of sperm-cell with germ-cell is at times absolutely necessary for the continuation of the species. You will be able to make yourself satisfied of the existence of this phenomenon amongst the infusoria, after some experience in the use of the microscope; so at present I will not make further remarks on the subject. Great patience is necessary if you would gain an accurate idea of the structure or functions of any minute organ of these little creatures. In no case is the old Latin proverb, "Nil sine labore," more true than in microscopic work; and the same may be said of the converse, "Labor omnia vincit."

What strange form of animal life am I gazing at now? A group of some dozen or more of creatures, each growing from a long, spirally-twisting stalk; some individuals, you see, are in the act of splitting, others have left the stalks; some are just beginning to uncoil, others are partly, others wholly uncoiled. The mouths, you observe, are surrounded with cilia. I will rub a little paint, say carmine or indigo, on this glass slide, and dip my camel-hair brush into it; now I let a little drop of this find its way between the glass cover and the slide on which the specimens I am examining lie. Now you see the action of these cilia. How the particles of colour are whirled about in all directions! How wonderfully rapid is the movement of these spiral stems, or foot-stalks! The name of this little creature is *Vorticella*, or the Bell Flower

Animalculæ (Fig. 17). Other interesting forms of the *Vorticellina* family you are sure to meet with, such as *Epistylis* and *Carchesium*. In individuals of the former genus, the flowers droop from a stem in a tree-like form, the footstalks having no retractile power; in *Carchesium* the bells or flowers spring from a single non-retractile trunk, but the stems, which are very numerous, are all retractile. On the stems and leaves of various aquatic plants you will see other interesting little creatures of the same family—each inhabiting a tube. A great number of species have been described; but you will recognise the general form when I tell you that the animalcule is like a Stentor. It is very curious to witness this animal protrude itself out of its case. Within its case, which is often very transparent, and which perhaps would escape your detection were

Fig. 17.—Vorticella.

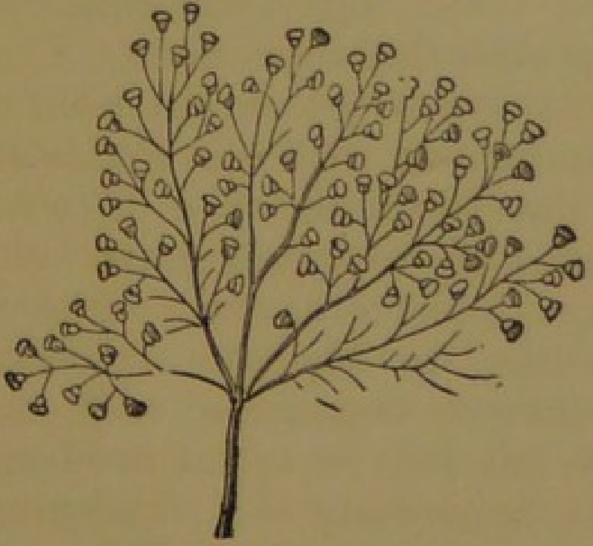


Fig. 18.—Carchesium.

it not for the small particles of dirt which have attached themselves to it, the animal is seen as a round mass. By-and-by it slowly extends itself till it reaches the open mouth of the tube; then the anterior orifice expands, the circlet of cilia is put in active motion, currents of food-producing water are brought within the action of the cilia, and, all of a sudden—quick as lightning—the little creature, by contraction of its muscular tissues, subsides into the form of a ball, as before. From their habit of living in a sheath these creatures are called *Vaginicolæ.*

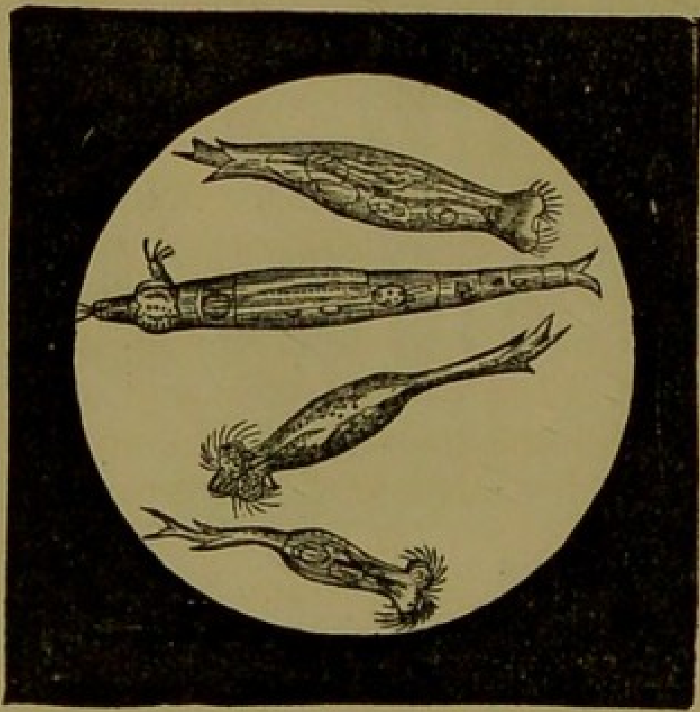


Fig. 19.—Wheel-animalculæ.

The wheel-animalcules (*Rotifera*) will afford you unlimited amusement and instruction. You will recognise their form from the accompanying figure. We advance a step most decidedly here. The animals that have hitherto come before our notice are of low organisation compared with the *Rotifera.* How shall we describe the structure of a *Stentor* or an *Ophrydium?* Imagine an animated mass hollowed out into one large general cavity. There is a mouth, with its circlet or circlets of cilia, and a stomach—some animal organisms, such as amæba and sponge, have not got so much even as this—a contractile vesicle, apparently the rudiments of a circulating system, and two *nuclei,* which represent the reproductive apparatus; but in the wheel-animalcule, and other *Rotifers*, you will see a differentiation of parts and a specialisation of organs. There is evidently an integument or skin through which certain viscera or internal organs can be discerned; one of the most conspicuous organs is what is sometimes badly named the gizzard. This piece of organic machinery, consisting of strong muscular substance, furnished, according to the species, with various pointed teeth, seems in these animals to be always going; its function is manifest even at a glance. You will notice that various substances, drawn down in the vortex caused by the action of the cilia, pass through this manducatory organ, which, like a pair of miniature mill-stones, grinds the food as it passes between them. You will often notice both eggs and young ones within the bodies of the wheel-animalcules, and very curious it is to see under the microscope the movements and contortions of a restless embryo rotifer. The Rotifera possess, moreover, an intestinal canal, a water-vascular system, and longitudinal muscles. There is much difference of opinion as to their proper place in the zoological scale. Some naturalists think that these wheel-animalcules have their affinities with worms, others with crabs.

You will be almost in ecstacies of delight at first becoming acquainted with the *Melicerta ringens*, an exquisite little creature, pretty common in pools and ditches, where it may be found sometimes in extraordinary profusion, attached to the stems and leaves of various aquatic plants. The Melicerta is a worm-like creature, about as thick as a horsehair, and the twelfth part of an inch in length. It is itself the architect of a very pretty little tubular house in which it dwells. You should try to make the acquaintance of Melicerta, for in the whole aquatic world there is scarcely a more interesting object for contemplation. Search for these creatures in mill-pools and ponds through which a current of water gently flows. If a portion of water-weed be brought home and placed in a glass vessel, and the leaves of the plants be carefully examined with a lens—the long thread-like leaves of the water crowfoot (*Ranunculus aquatilis*) are a very favourite habitat—you will probably detect delicate projecting objects of a reddish-brown colour, light or dark, however, according to the nature of the bottom of the pool. These are the tubular cases of *Melicerta*. If one of these, still attached to the bit of weed, be placed on a slip of glass, and viewed under the microscope with a power of about 50 diameters, you will notice that this tube is made of several series of round clay or mud pellets. By-and-by, if you will be careful not to shake the table on which the specimen is placed (for *Melicerta* is a coy and timid creature), you will see the occupant slowly unfold the anterior portion of its body from the orifice of the tube. At first, as Mr. Gosse has well described it, "a complicated mass of transparent flesh appears involved in many folds, displaying at one side a pair of hooked spines, and at the other two slender truncate processes projecting horizontally. As it exposes itself more and more, suddenly two large rounded discs are expanded, around which at the same time a wreath of cilia is seen performing its surprising motions. Often the animal contents itself with this degree of exposure, but sometimes it protrudes further, and displays two other smaller leaflets, opposite to the former, but in the same place, margined with cilia in like manner. The appearance is now not unlike that of a flower of four unequal petals; from which resemblance Linnæus, who compared it to a ringent labiate corolla, gave it the trivial name of *ringens*, by which it is still known."

By continuing to gaze on this marvel of creative skill, you will notice that it every now and then bends its corolla-shaped head down upon the tube, holding it there a second or two, and then raising it up again. What is the meaning of this? *Melicerta* is adding a brick to its house; sometimes you will see the bricks roll off after deposition, in consequence of the material not being sufficiently tenacious. The bricks are made of the same substance so generally used by human architects—namely, of clay, the only difference being that the bricks of the rotifer are round and soft. Under a power of about 200 diameters you will observe a singular cavity below the large discs of the head; this cavity gradually becomes filled with particles of clay; a number of cilia line the cavity, and by their action cause the particles of clay to rotate rapidly and to be consolidated. When the brick is formed the animal bends down its head and fixes it to the tube, and then begins to form another pellet. The particles of clay, or other adhesive material, are drawn into the cavity where the bricks are formed, by the ciliary action of the discs, a small channel conducting them from the upper portion of the disc to the cavity in question. If portions of indigo or carmine be mixed with the water in which the *Melicerta* lies, the animal will make use of them, and add rings of red or blue to its dwelling-place. It is impossible, I think, to imagine a more interesting instance of animal architecture than that exhibited by this little creature.

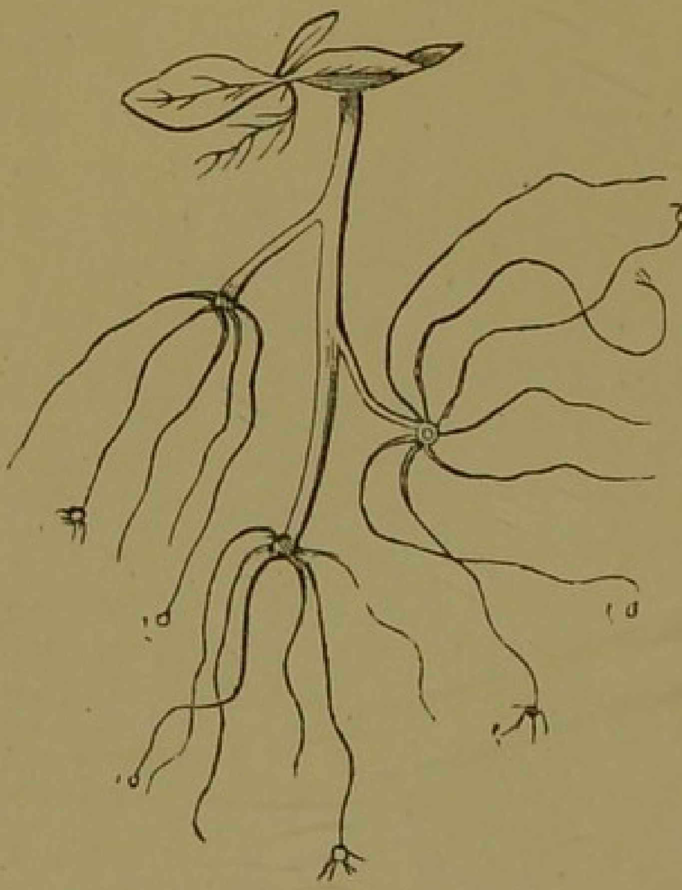
The Rotifera, from their great transparency, are excellent objects for study; many, forms, moreover are readily obtained—the scum attached to aquatic plants, the dirt in your pipes on the roof of your house, the soil on the roots of the moss of your slated roof, the mud at the bottom of ponds and ditches, will afford many specimens for examination. There is every variety of form: some are naked; others are loricated, or have a consolidated integument encircling their bodies; others construct houses in which they reside. Two beautiful forms, the *Floscularia* and *Stephanoceros*, will demand a short notice in the next chapter.

CHAPTER V.

USE OF THE MICROSCOPE IN ZOOLOGY (*continued*).

THE *Stephanoceros* and *Floscularia* are both very beautiful and delicate little creatures; they should be examined, to get a general idea of their form and characters, with a power of about 60 diameters. The former animal has an oblong body on a long tapering stalk; a circlet of fine elegant tentacles, with two rows of cilia on the sides, surrounds its upper portion; like the *Melicerta*, this little creature dwells in a tube, but not mechanically constructed, like that of the first-named animal. You will not easily satisfy yourself of the existence of this tube, so extremely transparent as it is; but by turning the mirror at different angles, you will notice a jelly-like case, which appears to be a secretion from the animal's body. Groups attached to weeds are visible to the naked eye; they prefer clear water, and may be kept alive for weeks in a vessel of water. On the slightest alarm, the Stephanoceros retreats within her cylindrical tube. *Floscularia* is another exquisite microscopic object, and common enough on the stems or leaves of water-plants. This creature, too, dwells in a transparent case; in form, it is like Stephanoceros, except that the head-portion is divided into six lobes or projections, each one having an immense quantity of extremely fine bristles. As the animal protrudes itself out of its case, these hairs appear in a dense mass, but soon the lobes separate, and the tufts of bristles on each spread themselves out in a graceful fan-like form. What is the use of these long bristles? I am unable to tell you. Although the animal is destitute of the ciliary wheel-like wings that characterise the Rotifera generally, its whole organisation, and the mechanism and functions of the grinding jaws or gizzard, clearly indicate its relationship with that class of animals. We must not linger more on these and similar exquisite little forms of animal life; let me direct your attention to a very strange-looking creature called the Hydra, of which genus there are three well-marked British species—namely *H. viridis*, *H. vulgaris*, *and H. fusca.* The first is of a beautiful grass-green colour, the second and third of a pale brown, sometimes nearly white. The arms or tentacles of the last-named species are very long. These animals are found only in fresh water, and generally such as flows very slowly or is quite still. As you will find the study of these creatures full of the deepest interest, I will give you a description somewhat fully.

The best way to obtain specimens is to take a handful of weeds from any clear pond or ditch, and place it in a glass vessel of water. After waiting half an hour the hydræ will probably be seen in various attitudes, some hanging loosely down, others gracefully curving themselves upward and throwing out tentacles many times longer than their bodies; others shooting up their arms above their heads; others contracting themselves into mere jelly-like dabs; others attaching themselves by both extremities to the side of the glass; others floating on the surface of the water, their-tail ends preserving them from sinking. Their colours, too, may be nearly as various as their attitudes—white, red, light flesh, or beautiful grass-green. The body of the hydra is of a gelatinous nature, altering in shape as it changes its position; when contracted, in some species a mere tubercle with short radiating papillæ; when extended, becoming a narrow cylinder. One end expands and forms an adherent disc; the other has a mouth surrounded by numerous exceedingly contractile arms or tentacles, varying in number according to the age and species of the individual. The hydra's body is composed of two membranes, technically termed *ectoderm* and *endoderm*, the former being the external covering, the latter the internal lining of the cavity. The tentacles are tubes, which are, in fact, prolongations of these two membranes. They are the arms by which the animal seizes its prey, and they are placed a little below the mouth, which, when closed, protrudes like a snout above them. Both membranes have irregularly rounded nodules on their surface. These nodules, especially in the tentacles, contain capsular bodies (thread-cells), in which may be seen (the hydra being crushed between bits of glass, under a high microscopic power) curious organs,



Hydra attached to a Weed.

consisting of spines and filaments, supposed by some to have the power of stinging. There are traces of muscular fibres in the tentacles, but whether sufficient to account for their extraordinary extensibility is doubtful. Some have supposed their elongation to be caused by the water, which, finding its way into the hydra's body through the mouth, may pass through extremely narrow channels into the tentacles. The tentacles of *Hydra fusca* are the most wonderfully extensible of all; growing gradually finer than the lightest gossamer, they become invisible except to the eye of the microscopist.

The hydræ are very voracious, and readily kept in confinement for some time. They feed on small *Entomostraca*, and on minute larvæ of gnats and naïd worms. Their stomach is a simple cavity. Some authors speak of a short narrow duct leading from the stomach to the centre of the disc, whence they say through a tiny aperture excrementitious particles may be seen to pass. Of this intestinal canal I have never discovered any sign in the species I have examined. Food is quickly assimilated by the hydra, and the indigestible portion expelled through the mouth, as in the *Actiniæ*. The movements of the hydra are very slow, but performed in the same manner as those of the leech, their position being also varied by a gliding motion of the disc. Sometimes this disc, protruded above the water, acts as a float, and the animal is borne along on the current. Hydræ may be found in spring, summer, or autumn, and in the latter season they give birth to eggs and die. I have found *H. viridis* in very mild winters. Their mode of increase is twofold—gemmation and the ordinary mode of reproduction. The first takes place throughout the summer, the latter only at the end of autumn. When increasing by gemmation, a small swelling first appears on the hydra's body; this grows larger, and divides at its apex into several minute papillæ, which afterwards become the tentacles. When reproducing by ova, the observer will notice certain peculiar elevations on the body of the hydra, some, in the middle of the body, round; others, at the bases of the tentacles, of a conical shape; perhaps one or two of each kind. The round elevations contain the ova; the conical, the spermatozoan bodies. The ovum, when ripe, pushed through the body-wall, and impregnated, becomes attached to some water-weed, and awaits the warm spring to be developed into the young hydra. But I have never succeeded in meeting with these detached ova, and they appear to have been only noticed by few. Trembley and Baker record many and various experiments practised by them on the hydra; and the former gives us a number of admirably executed figures. The result of these experiments may be summed up in the language of Dr. G. Johnston:—"If the body is halved in any direction, each half in a short time grows up a perfect hydra; if it is cut into four or eight, or even minced into forty pieces, each continues alive and developes a new animal, which is itself capable of being multiplied in the same extraordinary manner. If the section is made lengthways, so as to divide the body into two or more slips, connected merely by the tail, they are speedily re-soldered, like some heroes of fairy-tale, into one perfect whole; or if the pieces are kept asunder, each will become a polype, and thus we may have two or several polypes with only one tail between them; but if the sections be made in the contrary direction—from the tail towards the tentacula—you produce a monster with two or more bodies and one head. If the tentacula—the organs by which they take their prey, and on which their existence might seem to depend—are cut away, they are reproduced, and the lopped-off parts remain not long without a new body. If only two or three tentacula are embraced in the section, the result is the same, and a single tentaculum will serve for the evolution of a complete creature. When a piece is cut out of the body, the wound speedily heals, and as if excited by the stimulus of the knife, young polypes sprout from the wound more abundantly, and in preference to unscarred parts; when a polype is introduced by the tail into another's body, the two unite and form one individual; and when a head is lopped off, it may safely be engrafted on the body of any other which may chance to want one. You may slit the animal up, and lay it out flat like a membrane with impunity; nay, it may be turned inside out, so that the stomachal surface shall become the epidermis, and yet continue to live and enjoy itself, and the animal suffers very little by these apparently cruel operations,

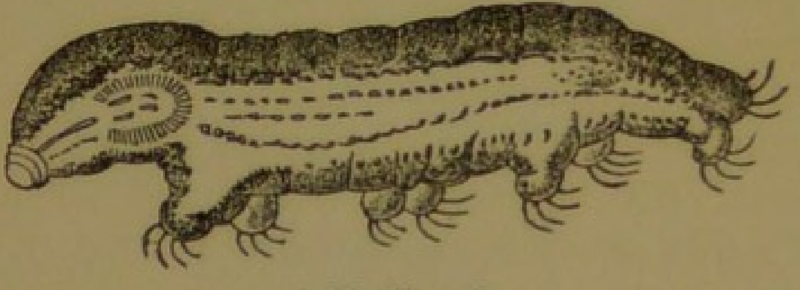
'Scarce seems to feel, or know
His wound,'

for, before the lapse of many minutes, the upper half of a cross section will expand its tentacula and catch prey as usual; and the two portions of a longitudinal division will, after an hour or two, take food and retain it. A polype cut transversely in three parts requires four or five days in summer, and longer in cold weather, for the middle piece to produce a head and tail, and the tail part to get a body and head, which they both do in pretty much the same time."

You will often notice some very interesting parasites upon the various species of *Hydræ*. One very curious little fellow delights to run up and down the hydra's tentacles, like a miniature railway-truck. In form the creature resembles a dice-box, only it is as broad as it is long; a wreath of cilia surrounds both the top and the bottom edges. Now it leaves the hydra, soon, however, to return to it again. The name of this little parasite is *Trichodina pediculus*. I am of opinion that these hydra-lice are indicative of a not very healthy condition of their hosts; but whether they are annoying or not I cannot say. The curiously-formed stinging organs of the hydra seem to be of no service in warding off these miniature *Trichodinæ*.

There is one curious creature which I must introduce to your notice, and which you may not unfrequently find in the surface mud of any pond. I shall never forget my first acquaintance with this animal, about twenty years ago. So struck was I with its absurd and grotesque appearance, having at that time but little acquaintance with microscopic forms, that I could hardly believe the evidence of my senses, and I called in a servant to look at the strange creature, and to tell me that I was not dreaming. Well, what was the creature? It was a *Tardigrade*, a very "slow-goer" indeed, but the strangest of beasts; it was something like a naked sloth, only it had four pairs of legs instead of two. These legs—such things to call legs—were each provided with four claws; there was no tail; its mouth was changeable in form, now blunted, now pointed with pouting lips. A curious oval-shaped muscular body, with peculiar style-like appendages was very conspicuous; this was the animal's gizzard. The style-like processes, or horny rods, are said to be protrusile; but though I have frequently examined *tardigrades* since I first made their acquaintance, I do not think I ever saw these rods in a protruded state.

These animals, like the rotifers, are capable of bearing exposure to very great heat without being any the worse for it; indeed, they were believed to be capable of resuscitation. Spallanzani has a chapter with the following heading: "Animals which can be killed and resuscitated at pleasure." Of course such an idea is absurd; the fact, however, remains that certain creatures, rotifers, tardigrades, anguillulæ, can be reduced by great heat to almost thorough dryness, can be kept in this condition for a length of time, and yet will revive on the application of moisture. Every one who is acquainted with the history of these animals is aware of the experiments made on them by M. Pouchet, so I shall conclude this chapter with an extract from "The Universe" of that distinguished French *savant:* "It is true we are, in our day, obliged to erase the charming romance of palingenesis, with which our forefathers amused themselves. Still, we must say that, although the Rotiferæ cannot be resuscitated when they are once dead, their tenacity of life is one of the most extraordinary phenomena. Their resistance to cold is something marvellous, and we do not even know where it stops; the lowest temperature that we can obtain in our laboratories does not seem to have any effect upon them. I have seen these animals defy a cold which would kill a man a hundred times over. Rotiferæ placed in an apparatus where the temperature was 40° below zero, Centig. (40° Fahr.), issued from it full of vitality."*



A Tardigrade.

"The natural history of the Rotiferæ is a

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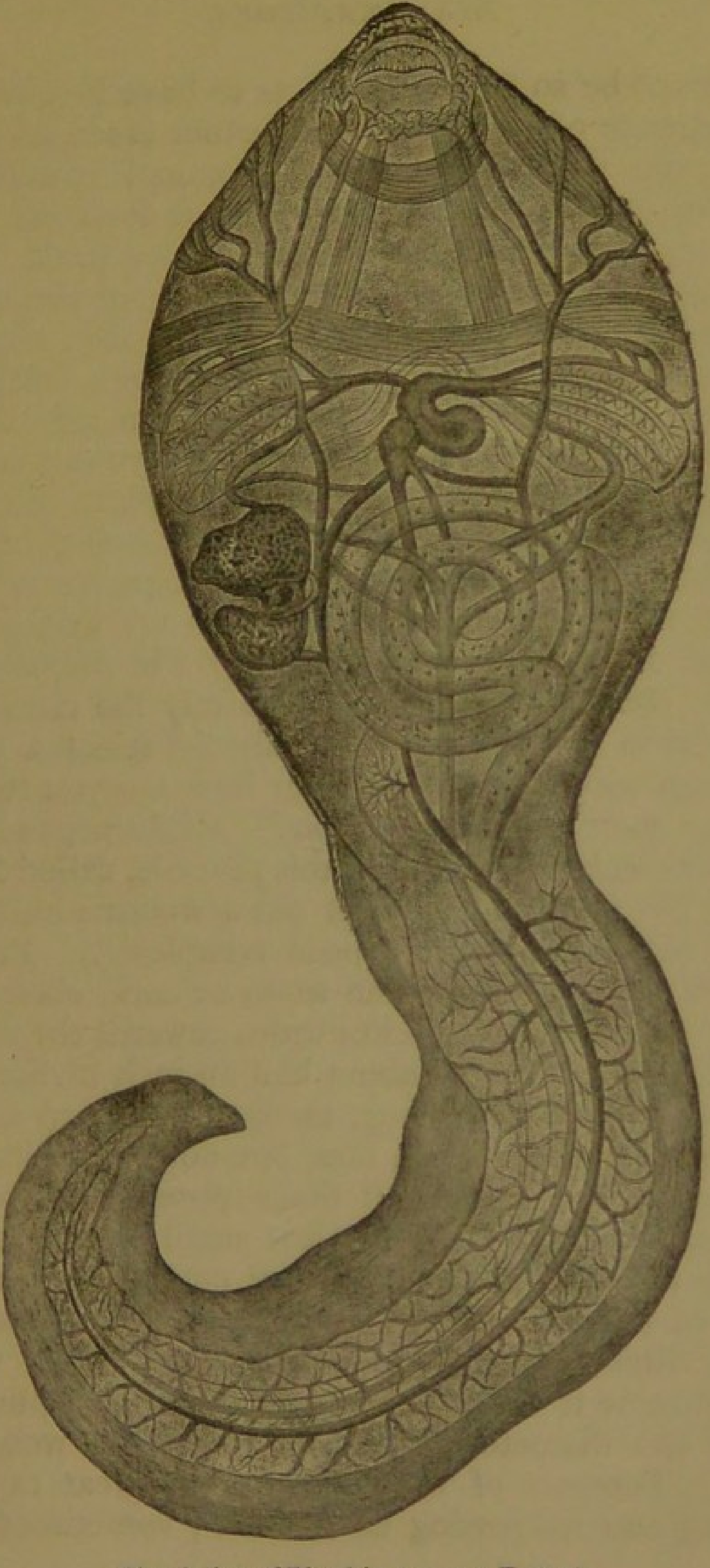
* "The Universe," p. 56.

marvel from beginning to end. I have sometimes removed them quickly from the freezing apparatus, and thrown them into a stove heated to 80° Centig. (176° Fahr.); when they emerged from this they were seen to recover their animation, and run about full of life. In this twofold test, and formidable transition from cold to heat, these Microzoa passed rapidly through a change of 120° Centig. (216° Fahr.) without being in the least inconvenienced by it." After what I have said and quoted, I am sure you will wish to make a few "slow-going" acquaintances.

CHAPTER VI.

USE OF THE MICROSCOPE IN ZOOLOGY (*continued*).

One of the most interesting spectacles afforded by the microscope is that which is furnished by the circulation of the blood. This may readily be seen in the gills of the tadpole or newt, in the tail of the tadpole, the foot and tongue of the frog, in newly-hatched fish, such as young trout, perch, sticklebacks, &c. The tadpole in its early stages of existence is essentially a fish, breathing the air contained in the water by means of external gills alone. If you will examine a very young tadpole, you will see these gills in the form of a pair of fringes at the sides of the head; at the bases of these are also the rudiments of the internal gills. The external gills rapidly disappear at the end of four or five days; but the internal gills, which were mere rudiments at first, are undergoing rapid development. "It is requisite," says Dr. Carpenter, "that the tadpole subjected to observation

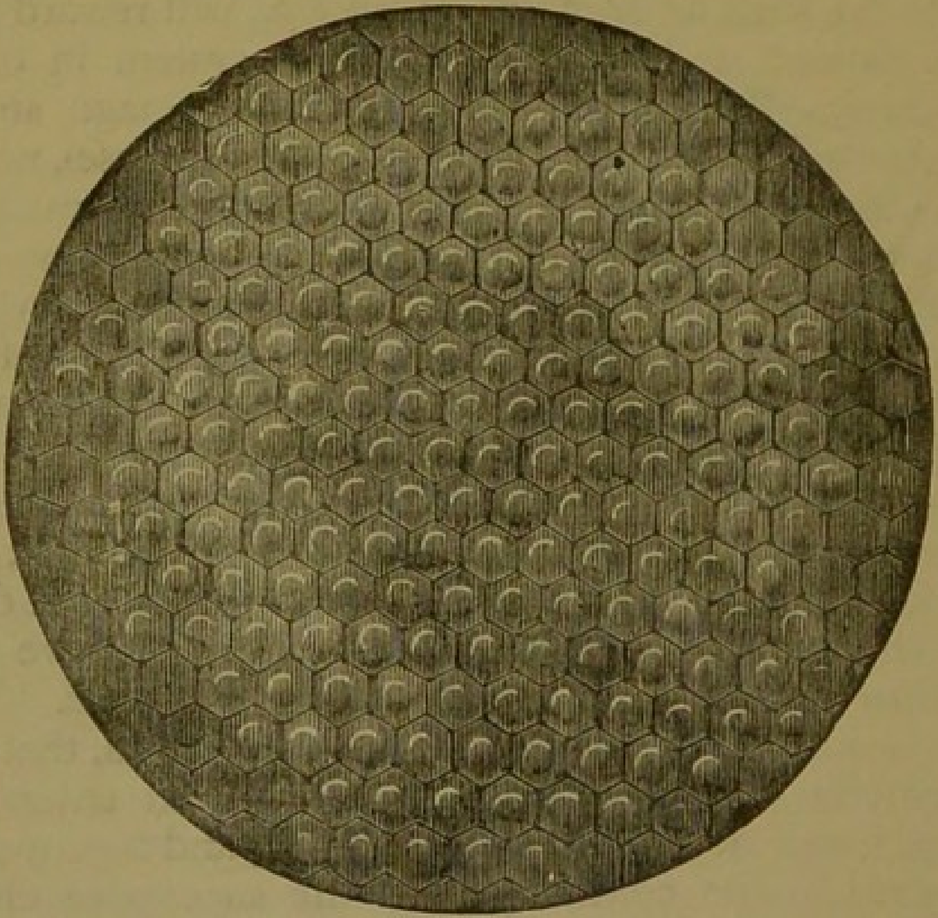


Circulation of Blood in a young Tadpole.

should not be so far advanced as to have lost its early transparence of skin; and it is further essential to the tracing out the course of the abdominal vessels, that the creature should be kept without food for some days, so that the intestine may empty itself. This starving process reduces the quantity of red corpuscles, and thus renders the blood paler; but this, although it makes the smaller branches less obvious, brings the circulation in the larger trunks into more distinct view." The circulation of blood in a young tadpole is a most astonishing spectacle. The plate will serve to give you some slight notion of the internal organs; by-and-by, when you become more experienced, you should read Mr. Whitney's remarks on that subject in Vol. X. of the *Transactions of the Microscopical Society*, 1862. If you desire to study the circulation of blood in a frog's foot, you should select a young specimen with a thin web. But how are you to keep the frog quiet under inspection? Microscope-makers sell an especial apparatus for this purpose, called a frog-plate; but you can easily cut out a wooden imitation, which will serve your purpose completely. Provide yourself with a piece of thin wood or cork, about nine inches long and three inches wide; towards the middle of its length cut a hole about half an inch in diameter. Wrap the whole of the frog, except one leg, in a piece of wet calico, and fasten him, but not too tightly, on the cork-plate; spread out the exposed foot over the aperture, and by means of a few small pins fasten the foot to the cork. Then put the cork-plate upon the stage of the microscope, and secure it by means of tape. Moisten the frog's web with a spot of water, and examine it under the microscope with a power of about 100 diameters, and you will see a wonderful sight. Torrents of blood flow with great rapidity, crossing and re-crossing each other; sometimes there is a momentary check, and the blood-corpuscles collect together in one spot. Perhaps the frog is too tightly fastened, or alarm may have interfered with the heart's action. You will notice several dark opaque bodies in the substance of the frog's feet; these are pigment cells.

The water larvæ of various kinds of insects, small crustacea, such as *Daphnia pulex*, &c., will reward you for a patient study of the circulatory system in these creatures. Both in the larva, pupa, and imago stages insects have not a heart, but a long dorsal vessel, which is really made up of a series of contractile cavities, one for each segment of the body, opening one into another from behind forwards, the whole being divided by valvular partitions. This is the typical form of the circulatory system. It must be confessed, however, that there is much difficulty in always making out these valvular partitions. The larvæ of any of the *Ephemeridæ* are capital objects for examination. A smaller specimen laid upon a glass slide, with a drop of water and a thin glass cover over it, will serve well to show you the circulation of blood in insects. You will notice that the blood is almost colourless, that the corpuscles are oat-shaped. "The current enters the dorsal vessel at its posterior extremity, and is propelled forwards by the contractions of the successive chambers, being prevented from moving in the opposite direction by the valves between the chambers, which only open forwards. Arrived at the anterior extremity of the dorsal vessel, the blood is distributed in three principal channels; a central one, namely, passing to the head, and a lateral one to either side, descending so as to approach the lower surface of the body. It is from the two lateral currents that the secondary streams diverge, which pass into the legs and wings, and then return back to the main stream. It is from these also that in the larva of the *Ephemera marginata* the smaller currents diverge into the gill-like appendages with which the body is furnished."

The various organs of insects will supply you with inexhaustible subjects for study and interest. A common fly from your window pane will furnish you with matter for examination for some time; and I would recommend the common fly as a sample of insect structure. Under a simple lens you will observe the numerous facets of the eyes, the number and position of the nervures on the wings; you may then select its various members for examination. Cut off the head, and view it as an opaque object by reflected light; you will notice that each eye is made up of numerous



Eye of Fly magnified.

little hexagonal figures, forming so many eyes, or *ocelli*, as they are termed. In the common fly the two eyes contain about 4,000 of these hexagonal facets, or *ocelli*. The eyes of insects differ according to the species, both in position, number, form, and colour. The eyes of the common white butterfly are composed of about 17,000 ocelli; in the dragon-fly there are upwards of 20,000.

By making a very careful vertical section you will discover that each *ocellus* is in shape like a pyramid; the upper part, or *corneule*, forming the base, the apex, or lower part, which is drawn to an extremely fine point, coming in contact with some delicate extremities of nerve-fibres which branch out from the optic nerve. It has been shown that each *corneule* is a double-convex lens, made up of the junction of two plano-convex lenses possessing a different refractive power, by which arrangement, probably, the aberrations are diminished, as they are by the combination of "humours" in the human eye. "That each 'corneule' acts as a distinct lens may be shown by detaching the entire assemblage by maceration, and then drying it (flattened out) upon a slip of glass; for, when this is placed under the microscope, if the point of a knife, scissors, or any similar object, be interposed between the mirror and the stage, the image of this point will be seen, by a proper adjustment of the focus of the microscope, in every one of the lenses."*

The pyramids, which consist of a transparent substance, representing, it is supposed, the "vitreous humour," are separated from each other by a layer of dark pigment, which at one point closes in, but leaves very minute papillary apertures for the entrance of rays from the *corneule*, which, passing down the pyramids,

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* "The Microscope," p. 662.

impinge upon the nerve-fibres at the apex of the pyramid. "Thus the rays which have passed through the several 'corneules' are prevented from mixing with each other, and no rays, save those which pass in the axes of the pyramids, can reach the fibres of the optic nerve. Hence it is evident that, as no two *ocelli* on the same side have exactly the same axis, no two can receive their rays from the same point of an object, and thus, as each composite eye is immovably fixed upon the head, the combined action of the entire aggregate will probably only afford but a single image, resembling that which *we* obtain by means of our single eyes."*

In other words, this explains the reason, and answers the question often asked, Why insects, which have so many eyes, do not see images of the same object as numerous as their eyes? I should mention that, besides these composite eyes, insects possess also rudimentary single eyes, like the spiders; these are situated on the top of the head; they are termed *stemmata*, and are generally three in number. It is a curious fact that the larvæ of insects undergoing a complete metamorphosis have these single eyes (*stemmata*) only; the two large composite eyes are developed during the latter part of the pupal life. If you have gained a fair knowledge of the structure of a fly's eye, you can pass on to another organ for study. Let us take the proboscis, with which we are all so familiar. The parts of the mouths of insects cannot fail to afford you an almost boundless source of gratification and delight, and notwithstanding their almost infinite varieties, they are always composed of the same essential elements. "You would not think so indeed; you would naturally suppose, looking at the

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* Dr. Carpenter, "The Microscope," page 663.

biting jaws of a beetle, the piercing proboscis of a bug, the long elegantly-coiled sucker of a butterfly, the licking tongue of a bee, the cutting lancets of a horse-fly, and the stinging tube of a gnat, that each of these organs was composed on a plan of its own, and that no common structure could exist in instruments so diverse."* But such is the case; underlying the great varieties of form in the details there is a common type. In order, therefore, to get some good definite idea of the typical insect mouth, you should examine the parts in that of a beetle, which possesses them in their most distinct form. You will notice, then, in a beetle (1) an upper lip, or *labrum;* (2) a lower lip, or *labium;* (3) a pair of jaws, or *mandibles*, which frequently are provided with strong teeth, and open laterally on either side of the mouth; (4) a pair of secondary jaws, *maxillæ*, situated beneath the mandibles; these serve to hold the food, the mandibles or biting jaws working on it, and to convey it to the mouth; (5) one or two pairs of jointed appendages attached to the maxillæ, called *maxillary palpi;* (6) a pair of *labial palpi.* The under lip, or labium, is generally composed of several parts, the basal part being called the chin, or *mentum*—a wide horny piece—the upper part being often much prolonged, forming what has been termed the *ligula.* Now, it is this tongue-shaped organ that we see so highly developed in the common fly, blow-fly, and other relatives. The plate, p. 64, represents a magnified view of the under side of the fly's tongue. The broad dark part at the bottom of the figure is the mentum; *b* is the portion formed by the metamorphosis of the maxillæ, being modified into a kind of sheath for the mandibles, which, in the fly, assumes the form of a pair of sharp cutting lancets.

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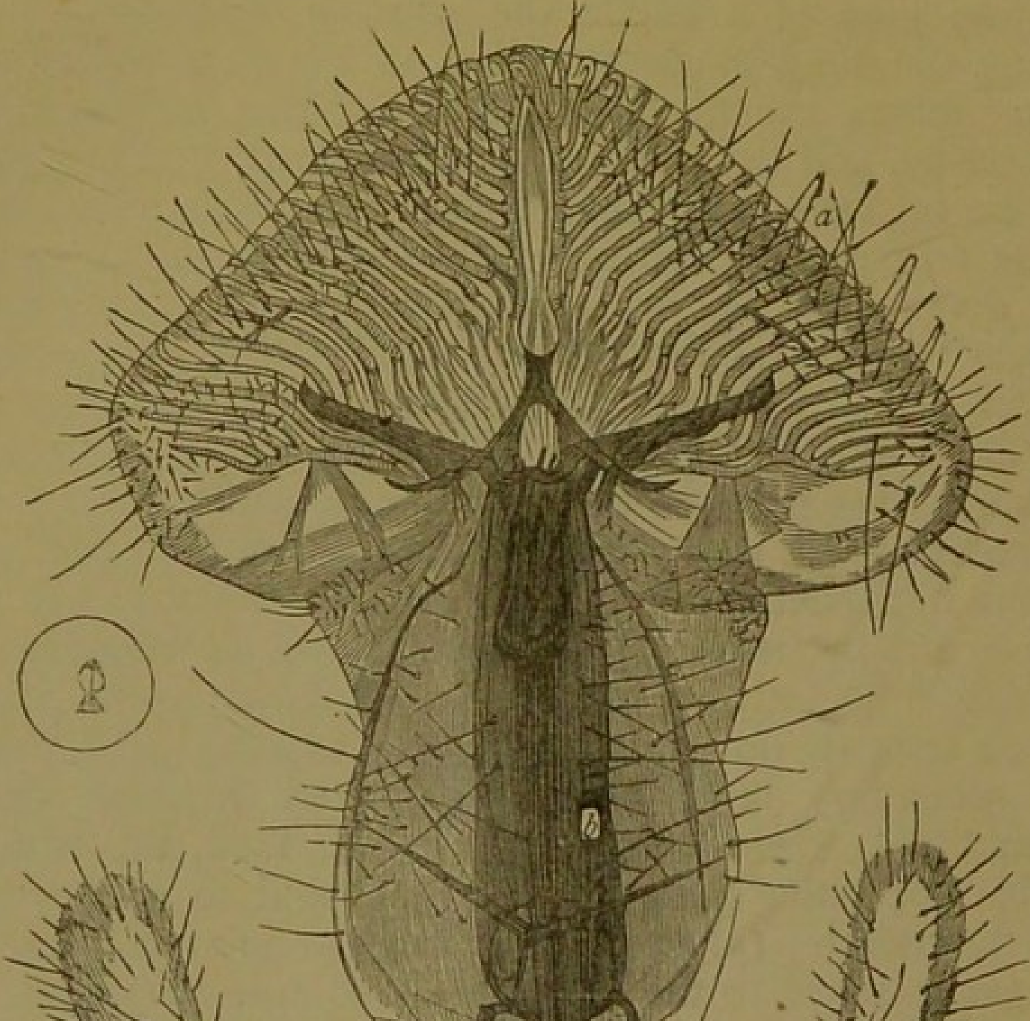
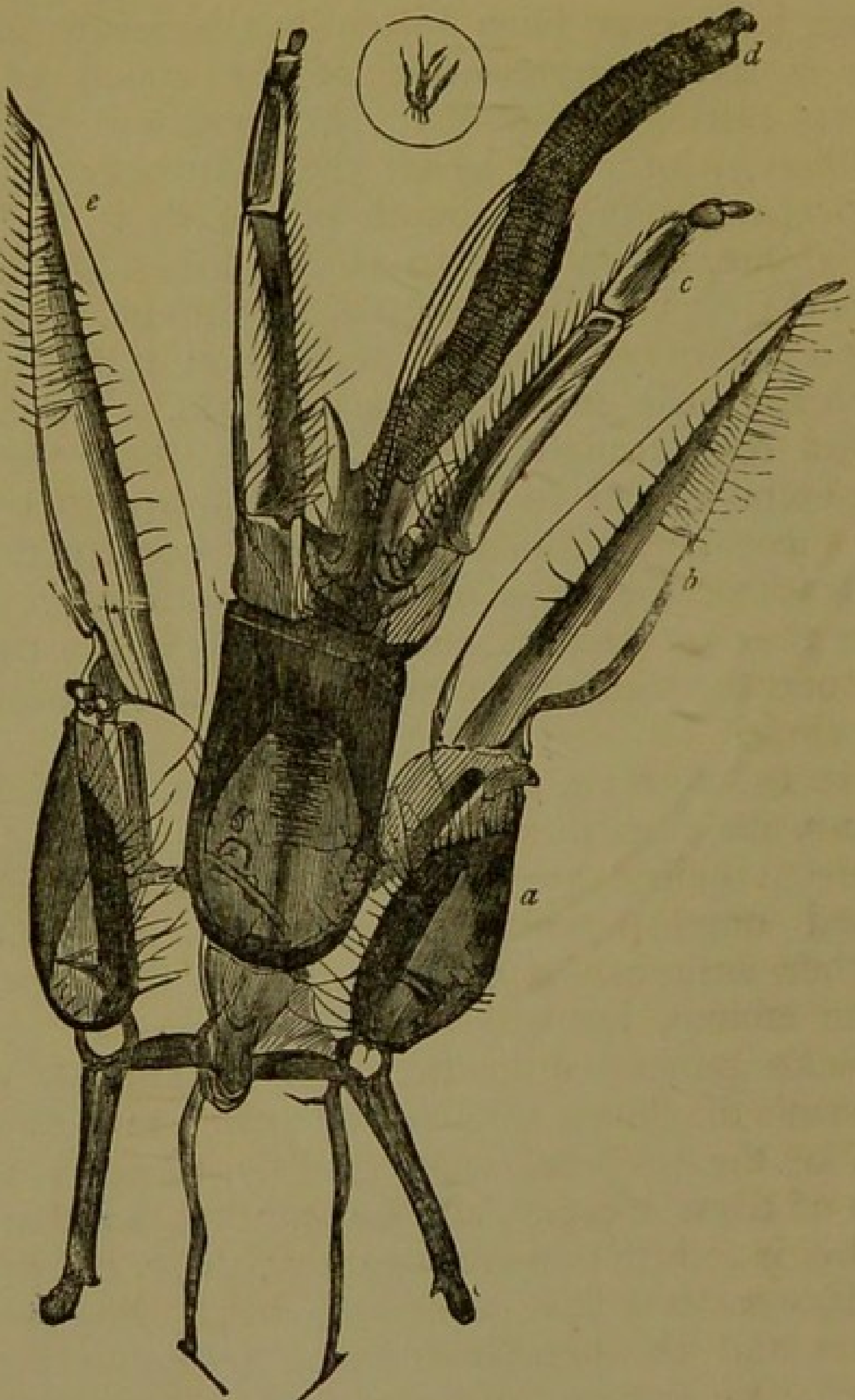
* Gosse's "Evenings at the Microscope," page 168.



Proboscis of Fly.

If you have ever been bitten by a horse-fly, you will have a lively appreciation of the effects of these lancets piercing your skin. At *c* you will notice the maxillary palpi. But by far the most beautiful piece of mechanism in the mouth of the fly is the end of the labium, which consists of two lobes forming the *ligula* (*a*). It is a wide muscular membrane, which contains a number of delicate semi-spiral tubes, through which the little insect sucks up fluids. These tubes remind one strongly of the *tracheæ*, those exquisite little spiral vessels by means of which insects breathe, only there is this difference in their construction—in the tracheæ the rings are a continuous spire, in the ligula they are distinct, and do not, as in the tracheæ, surround the whole tube, but perform about two-thirds of a circle.

"In the *Diptera*, or two-winged flies, generally, the labrum, maxillæ, mandibles, and the internal tongue (where it exists), are converted into delicate lancet-shaped organs. termed *setæ*, which, when closed together, are received into a hollow on the upper side of the labium, but which are capable of being used to make punctures in the skin of animals or the epidermis of plants, whence the juices may be drawn forth by the proboscis. Frequently, however, two or more of these organs may be wanting, so that their number is reduced from six to four, three, or two. In the *Hymenoptera* (bee and wasp tribe), however, the labrum and the mandibles much resemble those of mandibulate insects, and are used for corresponding purposes. The maxillæ, *c*, (see page 66), are greatly elongated, and form, when closed, a tubular sheath for the *ligula* (*e*), or 'tongue,' through which the honey is drawn up; the labial palpi (*b*), which are greatly developed and fold together like the maxillæ, so as to form an inner sheath for the 'tongue,' while the ligula itself



Mouth of Bee.

(*e*) is a long, tapering, muscular organ, marked by an immense number of short annular divisions, and densely covered over its whole length with long hairs. It is not tubular, as some have stated, but is solid ;

when actively employed in taking food, it is extended to a great distance beyond the other parts of the mouth; but when at rest it is closely packed up and concealed between the maxillæ. 'The manner,' says Mr. Newport, 'in which the honey is obtained when the organ is plunged into it at the bottom of a flower, is by "lapping," or a constant succession of short and quick extensions and contractions of the organ, which occasion the fluid to accumulate upon it, and to ascend along its upper surface until it reaches the orifice of the tube formed by the approximation of the maxillæ above, and of the labial palpi and this part of the ligula below.'"*

Head of Gnat.

The head of the gnat is a wonderful organ, and is provided with numerous sharp instruments, the effect of which when puncturing the skin is known to everybody. I ought, however, for the credit of the sex, to say it is the female alone that practises blood-letting, the males being harmless in this respect.

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* Carpenter's "Microscope," page 667.

The hemispherical head of the gnat, with its two large compound eyes, will be seen at once to be furnished with a long, cylindrical proboscis (*c*), a pair of antennæ (*a*), and a pair of labial palpi (*b*). This cylindrical proboscis is the homologue of the labium, or lower lip; it is covered with lined scales for a considerable portion of its length, and is expanded at the tip into three pairs of concave leaves. On the upper side of this proboscis is a groove, out of which spring six long, thin filaments (*d*), representing the mandibles, maxillæ, tongue, and labium. "The labium," writes Mr. Gosse, "does not enter the wound. If you have ever had the philosophic patience to watch a gnat while puncturing your hand, you have observed that the knob at the end of the proboscis is applied to the skin, and that then the organ bends with an angle more and more acute, until at length it forms a double line, being folded on itself, so that the base is brought into close proximity to the skin. Meanwhile the lancets have all been plunged in, and are now sunk into your flesh to their very bottom, while the *labium*, which formed merely the sheath for the whole, is bent up upon itself, ready again to assume its straight form as soon as the disengaged lancets require its protection."*

The proboscis, or *haustellum*, of the Lepidoptera (butterfly and moth tribe) will furnish you with a large stock of interesting matter for study. The long spiral organ must be familiar to the most casual observer. An examination of the structure of a butterfly's mouth will show us that the most important organs are here represented by the maxillæ, which are immensely elongated. The labrum and mandibles have their homologues in three small triangular plates, not easy to discover; the labial palpi appear one on each side of the spiral coil. The maxillæ are united, and form a

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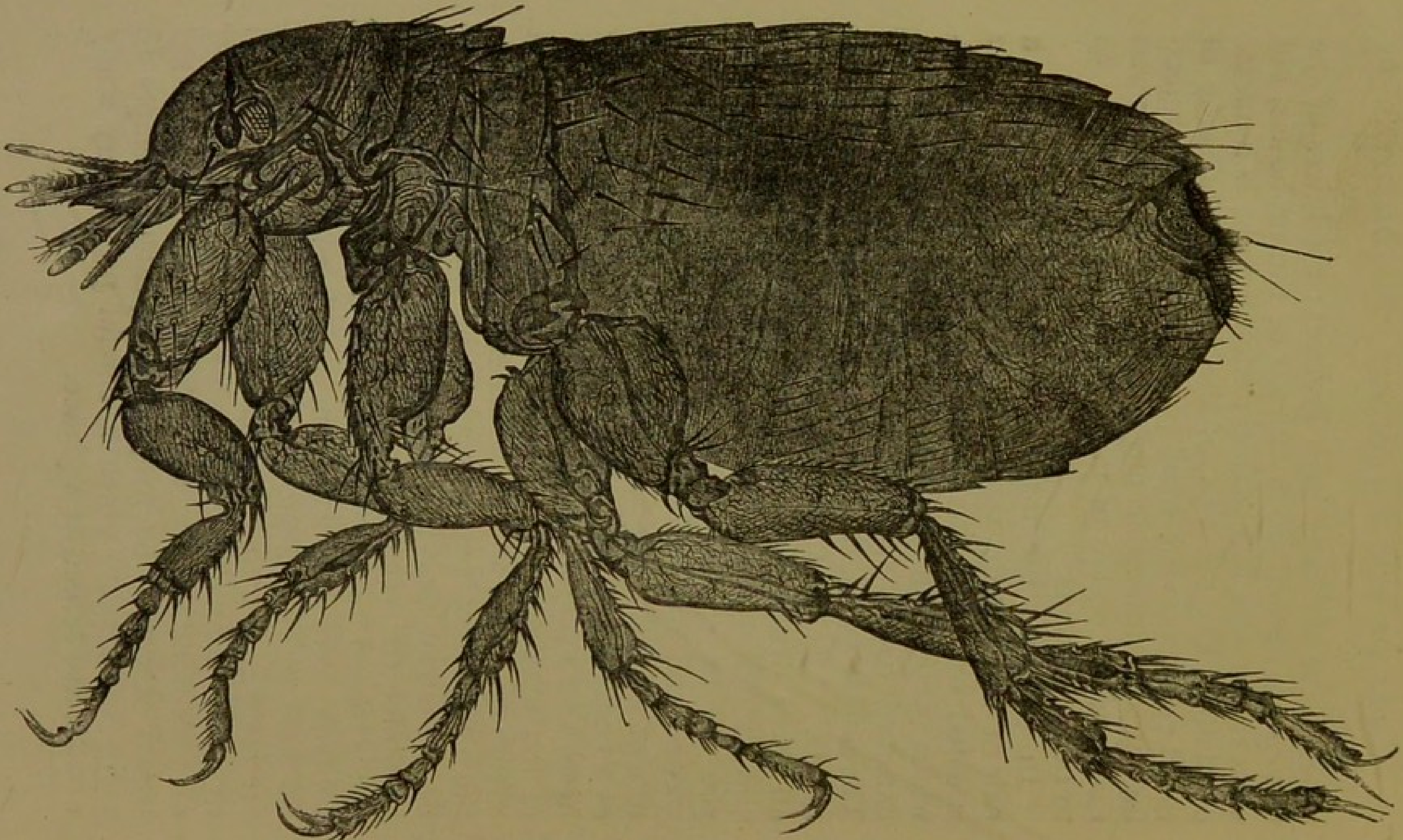
* "Evenings at the Microscope," page 183.

tube by the union of their grooves; the juices of the flowers are sucked up by means of the proboscis, but what the precise mechanical action may be is a matter of doubt. On the tips of the haustella of some of the Lepidoptera are small papilliform bodies, projecting at a considerable angle; it has been conjectured that they are organs of taste, but nothing is known as to their functions.

In the flea, the mandibles are represented by a pair of very sharp, razor-like instruments, which are situated on each side of the tongue; the maxillæ, which appear in the form of a pair of elongated flattened bands, serve as sheaths for the mandibles. The labial palpi also, in the flea, are cutting instruments. You must not expect to be able to make out all these details without a good deal of patient care, and without many failures at first; but persevere, and you will be rewarded by success in time. I would recommend you to begin with the study of the structure of insects' mouths, by selecting some large beetle, as a cockchafer. After you have killed it, cut off the head, and examine the various parts with a low power of the microscope. Place the head in a gutta-percha trough of water, and with dissecting-needles separate the component parts, viewing the insect's head first on the dorsal aspect, then on the ventral; be careful to notice the relative position of the parts, and do not proceed to the examination of another species till you have thoroughly mastered one. You lose no time by such a proceeding; on the contrary, you are really saving time, because the knowledge acquired by such thorough kind of work will so imprint itself on your mind, that you will be saved much time that would otherwise be lost, from repeated attempts to verify some point which a careful preliminary study would have settled at a glance.



Flea magnified).

CHAPTER VII.

THE MICROSCOPE IN ZOOLOGY (*continued*).

EVERY part of an insect is worthy of attentive study; the head with its various appendages, the wings, legs, eyes, spiracles, stings, and ovipositors, &c. &c., will come under your examination. You must often have been struck with the extraordinarily rapid movements of various insects through the air. You have been lying awake in an early morning on your bed, and have noticed the ease and grace with which the little house-fly performs, in company with his companions, his dancing gyrations. Now one individual darts backwards with the rapidity almost of thought, and another is soon seen to accomplish the same feat. Her gauze-like wings, moved by the strong muscles of the thorax, vibrate 600 or 800 times in a single second, and even considerably more if she will it. Our little fly, say Kirby and Spence, in her swiftest flight will go more than the third of a mile a minute. Now compare the infinite difference of the size of the two animals (ten millions of the fly would hardly counterpoise one racer), and how wonderful will the velocity of this miniature creature appear! Did the fly equal the racehorse in size, and retain its present powers in the ratio of its magnitude, it would traverse the globe with the rapidity of lightning. The organs by means of which such wonderful results are accomplished must be worthy of your patient examination. The wings of many insects, as bees and

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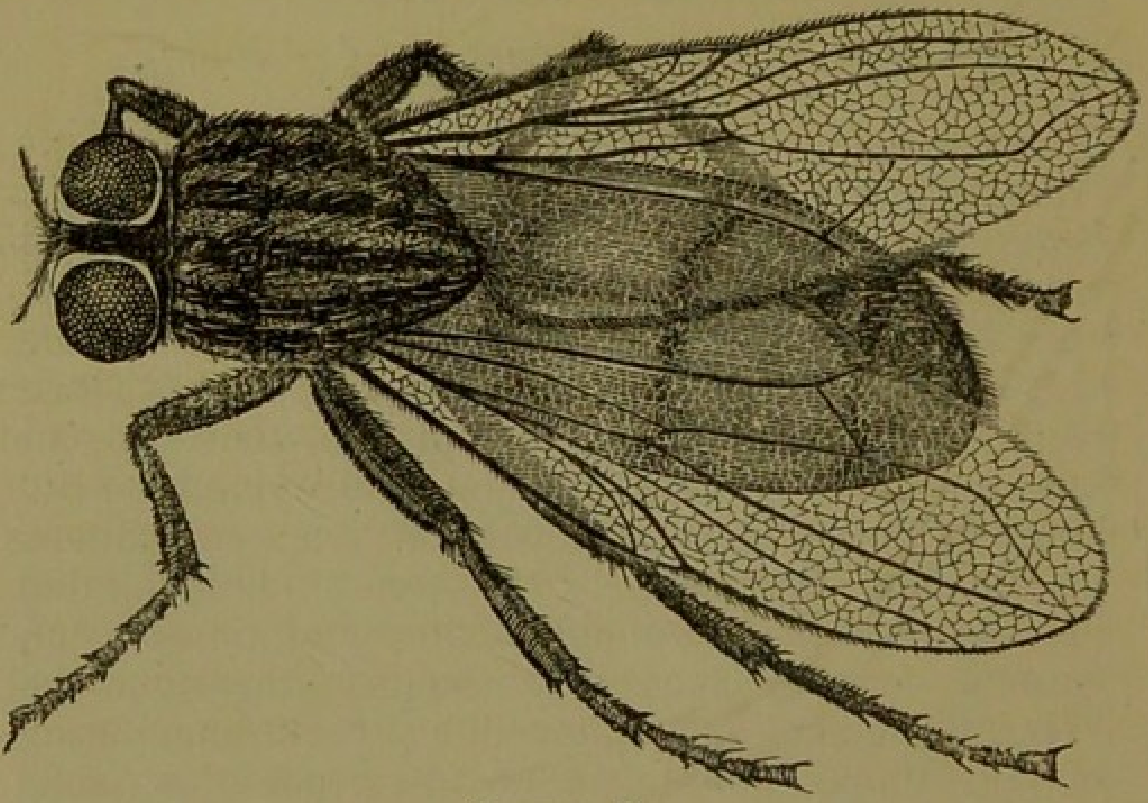
"Introduction to Entomology," vol. ii., p. 362.

wasps, dragon-flies, two-winged flies, are made up of a double layer of membrane, with a number of veins or "nervures," within which there are generally found air-vessels, or tracheæ. These nervures, by their subdivision and reunion, form in some cases an exceedingly beautiful network; this is especially observable in some of the smaller *Neuroptera*. Besides spiral vessels, or tracheæ, the nervures contain a fluid supplied from the body, so that both air and blood circulate in them; the membrane of the wing often presents an appearance of cellular areolation, as you will see in the above figure of the common fly. Although to the unassisted eye the membrane appears to be clear, transparent, and homogeneous, under the microscope you will see it is covered with short stiff hairs; in the fly there is a single hair in each areola, of the form of a curved spine. In the wings of the *Hy-*

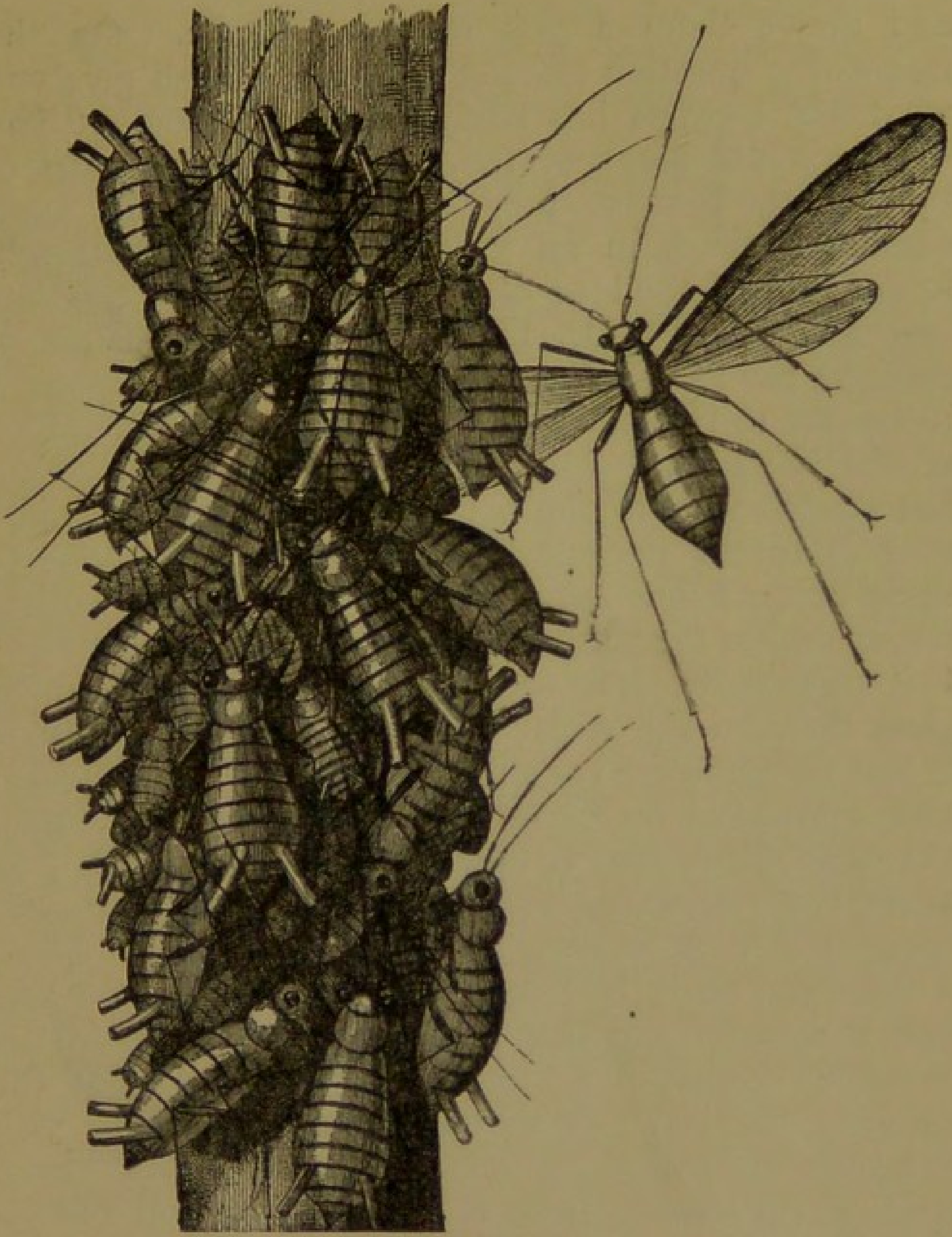


Common Fly.

menoptera—as the bees, wasps, &c.—there often exists a beautiful apparatus for connecting together the two wings on either side, so that they may present one large flat surface wherewith to strike the air and not overlap one another; along the front edge of the hind wing there is a row of curved hooks; the front wing near its base is doubled over so as to form a groove or slit into which the hooks fasten. You will see this structure readily enough in the wings of the wasp. In some insects the wings are strengthened by a thick layer of horny substance intervening between the two membranes, as in the *Coleoptera*, or beetle tribe, where the front wings are no longer instruments of flight, but coverings for the hind wings. In the *Orthoptera* (grasshoppers, crickets, &c.) the front wings contain much horny matter, but they are not consolidated to the same extent as in the beetle tribe. If you will examine a fly or other two-winged insect, you will notice at the base of each of the front wings two small projecting organs (*halteres*), the rudimentary representatives, it is believed, of the posterior wings. What is the function of the *halteres?* Dr. Braxton Hicks considers they minister to the sense of smell. Mr. Lowne, in his recent excellent monograph on the anatomy of the blow-fly, thinks they are organs of hearing. Each *haltere* is a little fleshy cylinder terminating in a small knob, having a thickened base clothed with fine hairs. The globular extremity is hollow, according to Mr. Lownes, and contains numerous round spots, which he regards as *otoconia.* The wing of the house-cricket contains the apparatus by means of which its well-known characteristic sounds are produced. I have a specimen before me as I write. On each of the upper wings there is a large clear space of a sub-triangular form, bounded on one side by a thick dark-coloured nervure with three or four longitudinal ridges; the inner margin of this nervure spreads out into a thin, narrow membrane; other nervures, much smaller than the dark one, border the space which forms a drum, or *tympanum*. In front of the drum is clearly to be seen a transverse side with numerous file-like teeth, from the middle portion of which side there proceed three nervures; two are simple; the other, which is connected at the base to the file by three short and strong processes, branches into two parts. All these three nervures are strong at the base, and then become attenuated; they stretch across the tympanum till they touch and become part of the narrow membrane of the large dark nervure spoken of above The insect then produces the sound by rubbing the wings together; the files are rapidly drawn one across the other, and the sound greatly intensified by the action of the drum, or tympanum, I have endeavoured to describe. I ought, however, to say that some observers believe the sound is produced by the rubbing of the file across the large longitudinally-ridged nervure. It would be difficult to decide the point, but I can readily conceive either mode would produce the well-known sound.

You will be struck with the beautiful iridescent hues observable in the wings of some insects. The aphides, or plant-lice—those noxious pests known to farmers as "smother fly," and to the popular mind as "blight"—exhibit this iridescence in a remarkable degree. By turning the wing you may be examining to various directions, you will ascertain the angle at which the iridescent hues are best seen.

The feet of insects will be sure to occupy your attention, and their study to afford you delight. The foot of the house-fly is a very common microscopic object, and one especially interesting. It has long



Plant Lice.

been a question how the fly and other insects can maintain their position in an inverted attitude. The foot, or *tarsus*, of the fly consists of five pieces, "the first of which contains a pair of muscles which move the second upon it, but the remaining four contain none." The last joint has a pair of pads (*pulvilli*), and above them a pair of sharp hooks. On the interesting question alluded to above, I shall give you what Mr. Lownes has lately written thereon. "The foot-pads are amongst the most interesting parts of the insect, because they enable it to walk upon smooth surfaces in an inverted position, apparently in defiance of the laws of gravity. Long ago this was first ascribed, by Dr. Derham, to the exhaustion of air from the foot-pads; recently it has been supposed to be due to the exhaustion of air from the extremities of the hairs with which the pad is closed; others have ascribed it to the hold which these minute hairs take of trifling irregularities of surface; but none of these explanations are correct, and one of the earliest notions upon the subject is the nearest to the truth—that is, that the feet secrete a glutinous fluid which glues them to the surface on which the insect walks. When the pads are carefully examined, it will be seen that they have no cup-shaped cavity beneath them, but that they are hollow with a nipple-like protuberance projecting into each. This will be seen more plainly by pressing upon the tarsus which forces it into the pad; by cutting off the end of the pad first it may be exposed in this manner, and will be found to consist of a closed sac. This sac fills the whole of the last four tarsal joints, and is lined with pavement epithelium; it secretes a perfectly clear viscid fluid, which exudes from it into the pad, and fills its cavity, as well as the hollow hairs with which its under surface is covered. These hairs open by trumpet-shaped mouths, and the disc of each mouth is kept full of the fluid. Sometimes, when the insect is captured and held between the finger and thumb, it exudes so rapidly that the pads are soon covered with a little glistening drop of it, which may be collected upon a glass slide, where it rapidly solidifies. It is insoluble in water, and solidifies under that fluid. The whole contents of the tarsus becomes solid very rapidly as soon as the insect is dead, or the part is removed.

"There is no essential difference in the pads of flies and the *pulvilli* of beetles, moths, and other insects; the same fluid is secreted in all. The only difference is that the pads of flies are membranous and transparent, instead of hard and opaque.

"The feet of the smaller house-fly are the best to show the manner in which the viscid fluid exudes from the extremities of the trumpet-shaped hairs, as they are very large in this species, and a glistening bead of fluid can be seen plainly at the extremity of each hair by placing the living insect under the microscope. The footprints left upon glass by flies consist of rows of dots corresponding to these hairs; this is best seen in those of the lesser house-fly from their greater size. The whole appears precisely analogous to the manner in which caterpillars and spiders suspend themselves by silken threads. In both cases the fluid is exuded from minute pores, and bears the weight of the insect, the only difference being in the nature and quantity of the fluid exuded. Much discussion has arisen as to the manner in which flies liberate their feet, and it has even been objected that they would become so firmly adherent after a time that the insect would be glued to the spot. Nothing can be simpler than the arrangement by which the foot is liberated, and in the healthy insect the secretion probably never becomes solid as long as

Foot of Fly magnified.

it remains in contact with the foot. It is sufficiently glutinous, even in the fluid, or rather semi-fluid, state it assumes as it exudes, to sustain the weight of the insect, when the strain is put equally upon all the hairs, of which there are about 1,200 on each pad; but when the pad is removed obliquely, so that each row is detached separately, the resistance amounts practically to nothing. A neat experiment will demonstrate this, even to the most sceptical. If a piece of adhesive label be cut for convenience into a pear-shaped disc, an inch in diameter, and caused to adhere to the hand by slightly damping it, a force of many pounds applied to the narrow extremity in the axis of the paper will not stir it, whilst it is immediately removed with very little resistance, when the force is applied so as to lift it gradually up.

"The direction and length of the hairs upon the pad are so adapted to the oblique direction in which the strain is put upon them when the tarsus is straight, that the insect has a perfectly secure hold; this is immediately released as soon as the tarsus is curved, which is effected by the long slender tendon already mentioned. In the small house-fly, the pads themselves are capable of being curved, for the tarsal tendon branches, and is inserted into the distal extremity of the pad."*

I will select one more insect's foot for examination, and that shall be the hind-foot of the bee. I have just caught a hive-bee as it was gathering pollen from mignonette, a flower to which bees resort much for the sake of the pollen-grains. I see on each of the hind-legs a reddish-yellow globular mass of substance adhering to its middle portion. After killing the bee by putting it under an inverted tumbler with some

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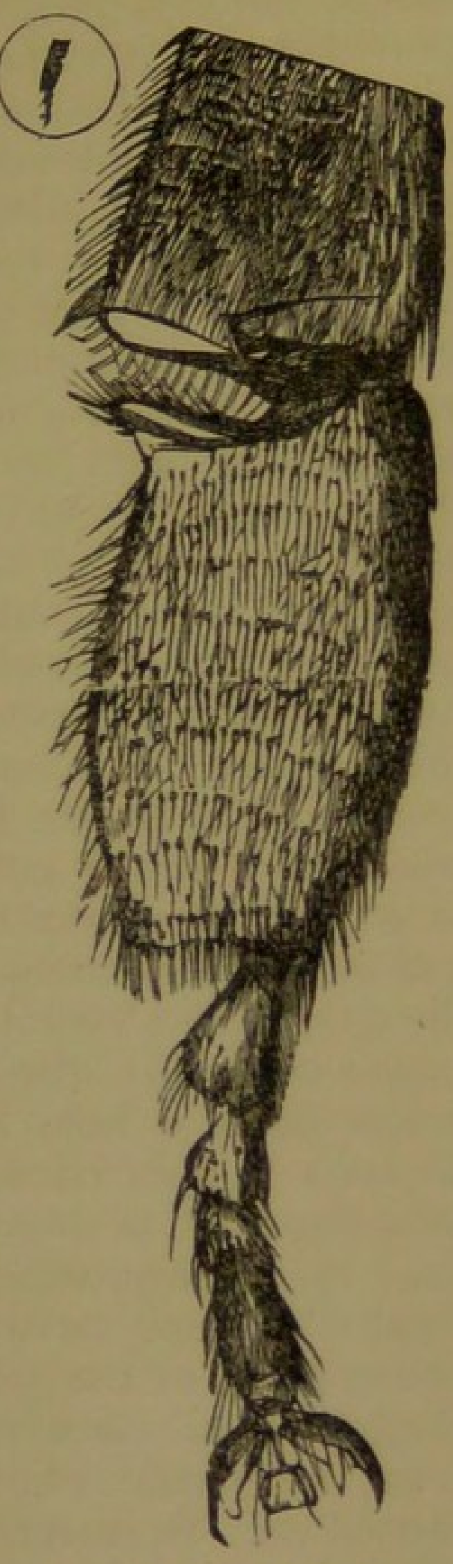
* "Anatomy of the Blow-fly;" pp. 20—22.

bruised laurel leaves (the effect of the fumes of prussic acid on bees is very rapid), I cut off its hind-legs, and with a camel's-hair brush and water wash away that pollen mass. At the juncture of the femur and tibia I notice a deep nick or cavity, and on submitting this to microscopic investigation, I find a number of reddish-coloured spines arranged around the cavity of the femur; the upper part of the tibia is also hollowed out into a cavity; the remaining part of the tibia contains a number of brushes or hairs, by means of which the pollen is taken from the flowers of various plants. But how does the pollen get from the brushes into the pocket? It is evident this cannot be done from the same leg. The bee rubs the pollen-grains off one leg into the pocket of the other, and the series of strong comb-like spines render material aid in their deposition there. When the bee is loaded, off she flies to the hive, where the pollen mass is mixed with honey, deposited in cells, forming the "bee-bread" with which the young bee-grubs are fed.

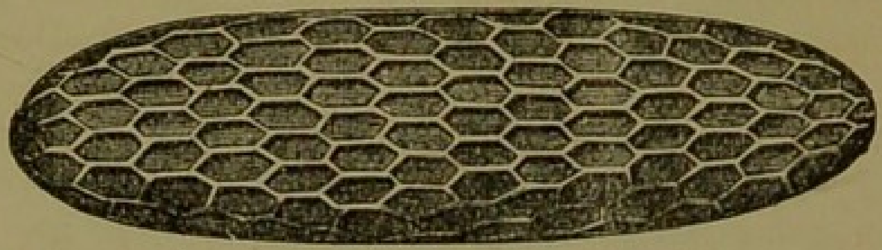

Hind Foot of Bee.

The stings and ovipositors of insects are very interesting objects to study. The *Hymenoptera* will afford numerous forms of these instruments. In the bees, wasps, hornets, ants, the last segment of the body is provided with a sting; the ichneumon, saw-flies, gall-flies, are furnished with an ovipositor; in external form there is not very much difference between an ovipositor and a sting. The sting consists, in wasps, bees, &c., of two very sharp dart-like organs, with barbed teeth at their points; this apparatus is enclosed in a horny, elongated sheath; near the root of the sting you will find a membranous bag, which contains a poisonous fluid; between the darts there is a canal, down which the venom is poured into the wound made by them. The ovipositors of insects differ somewhat in form, but they all consist of a long tube protected and covered by a cleft sheath. That curious hymenopterous insect, not uncommonly met with in this country, the *Sirex gigas*, and generally taken for some kind of hornet by the ignorant of such matters, has a very strong ovipositor, by means of which the insect can bore into hard timber. The *Cynipidæ*, or gall-insects, so extremely common on various parts of the oak, have a very delicate ovipositor, with a toothed edge; using this instrument as a kind of saw, the little insect bores a hole in some part of the tree, and deposits therein its egg. It is supposed that some irritating fluid is dropped into the hole at the same time as the egg, which produces what are known as "galls." These serve both as shelter and food for the young grubs of the gall-flies. You will be struck with the beauty of the spiracles and tracheal system of insects, the apparatus by means of which the respiration is carried on. In insects the blood is oxygenated by the admission of air into every part of the body, even into the most minute; the air enters through the spiracles, which are situated at each side of the body, and passing down the tracheæ, which branch off into numerous ramifications, is conveyed to every part of the system. "The structure of the air-tubes," as Dr. Carpenter says, "reminds us of that of the spiral vessels in plants, which seem destined (in part at least) to perform a similar office; for within the membrane that forms that outer wall, an elastic fibre winds round and round, so as to form a spiral closely resembling in its position and functions the spiral wire-spring of flexible gas-pipes; within this again, however, there is another membranous wall to the air-tubes, so that the spire winds between their inner and outer coats." There is much difference in the form of the spiracles, or *stigmata*, as they are also called; but in most cases the opening is protected by a sieve or grating formed by hairs or branches of the integument; these prevent particles of dust, &c., from getting into the air-vessels. Some of the large caterpillars of the Sphinx-moths show the stigmata very clearly even to the naked eye.

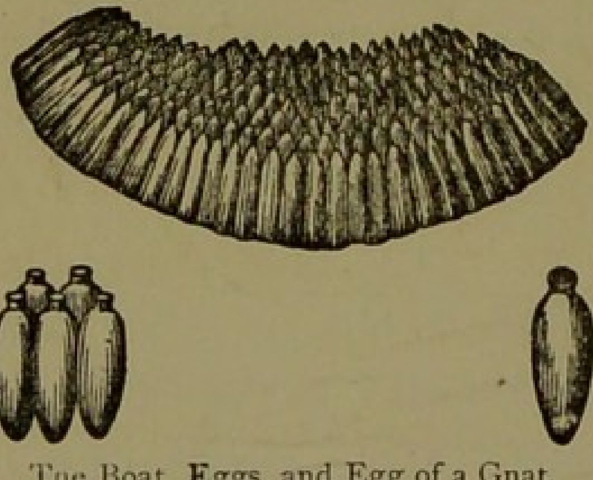
CHAPTER VIII.

THE MICROSCOPE IN ZOOLOGY (*continued*).

You will find much to admire in the examination of the eggs of insects, which are often of great beauty. The butterfly tribe (*Lepidoptera*) furnish some of the most interesting forms, and those of the garden white or cabbage butterfly are too common on the leaves of that vegetable. The eggs of the water-scorpion (*Nepa cinerea*) are very curious; they are of an oval form, and one end is surmounted by seven stiff reflexed hairs or filaments. The eggs of the mangold-worzel fly (*Anthomyia betæ*) have their surfaces very symmetrically marked. In the summer of 1861 these flies were so numerous that they committed serious damage on the crops in many parts of England. From the eggs are produced small larvæ, which at once bore a hole in the leaves, and tunnel between the cuticles; whole fields soon present an appearance as if the leaves of the plants had suffered from some scorching influence. The larvæ, when full grown, drop out of the leaves and turn to pupæ in the earth. The eggs of the common gnat (*Culex pipiens*) are deposited, by the aid of the insect's hind-legs, in a small boat-shaped mass, which floats upon the surface of the water. They are of a longish oval form with a small knot at the top, and all are packed closely together. The larvæ, whose peculiar twistings and jerkings must be familiar to everybody who has ever looked into a rain-tub, are very active little creatures, and interesting objects for microscopic study.

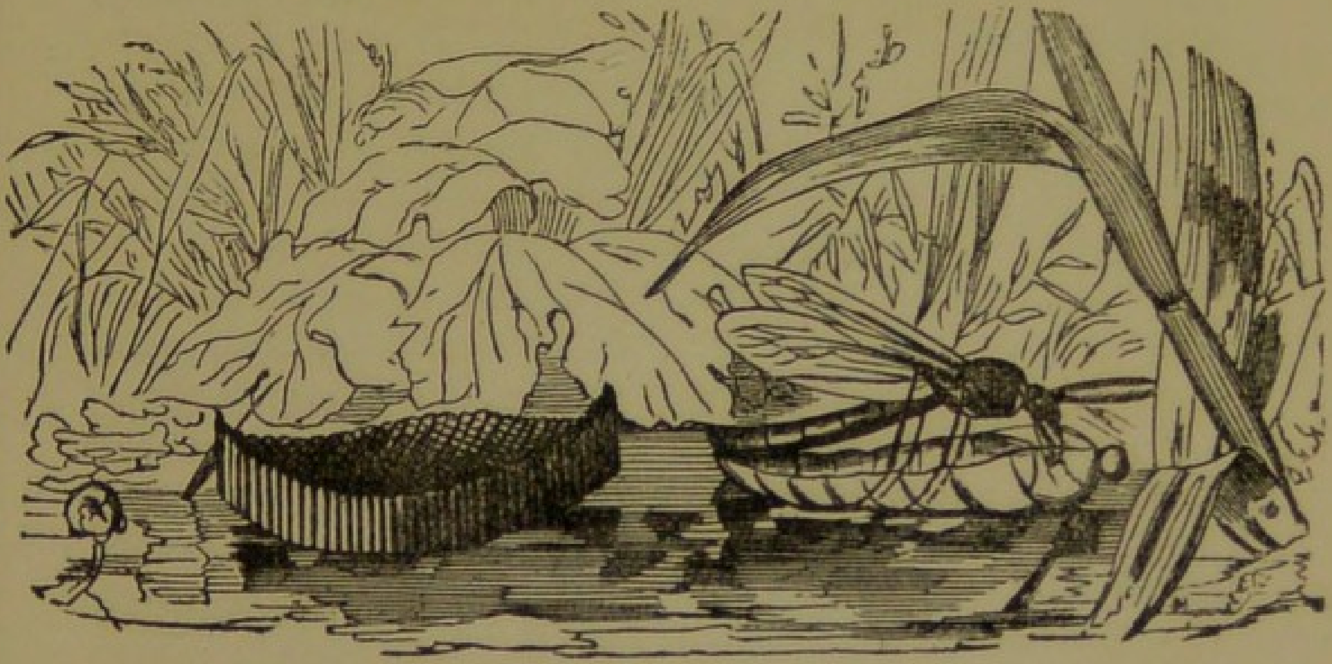


Egg of Mangold-Worzel Fly magnified.



The Boat, Eggs, and Egg of a Gnat.

The hairs and scales which beset the surface of many insects will long afford you delight. The dust which so readily comes off the wings of butterflies and moths will be found to exhibit, under the microscope, very beautiful forms. These scales are deposited in regular layers upon each side of the membranous wings—for if you rub the dust off the wings, you will see they are membranes—like the tiles on the roof of a house. It is the scales that give the brilliant hues to the wings; one patch being red, another green, another brown or yellow. There is great variety of form in the scales even of the same insect; those on the wings are generally broad, those on the legs long and slender. Now examine carefully the form of a single scale; you will see that each one is furnished with a short pedicel or foot-stalk; carefully wash away all the dust off the wing you are examining, and attend to the membrane only. You will see regular rows of small sockets; into these sockets the foot-stalks of the scales are fitted. The foot-stalks of the scales vary according to the species. The little azure blue butterfly (*Polyommatus Alexis*), so common in the summer months, will supply you with a form of scale termed "battledore scale," the foot stalk of which forms quite a long handle. These scales are marked by longitudinal ribs, which swell into round elevations



The Gnat and her Boat of Eggs.

at intervals, each with a black point in its centre. The metallic lustre of the scales of the diamond beetle of South America (*Curculio imperialis*) will astonish you from its gorgeous magnificence. I have a specimen before me as I write, but I cannot describe it better than in the words of Mr. Gosse. "We look at it by reflected light, with a magnifying power of 130 diameters. We see a black ground on which are shown a profusion of what look like precious stones, blazing in the most gorgeous lustre. Topazes, sapphires, amethysts, rubies, emeralds seem here sown broadcast, and yet not wholly without regularity, for there are broad bands of the deep black surface where there are no gems, and, though at considerable diversity of angle, they do all point, with more or less precision, in one direction—viz., that of the bands. These gems are flat, transparent scales, very regularly oval in form, for one end is rather more pointed than the other; there is no appearance of a foot-stalk, and by what means they adhere I know not. They are evidently attached in some manner by the smaller extremity to the velvety black surface of the wing-case. The gorgeous colours seem dependent in some measure on the reflection of light from their polished surface, and to vary according to the angle at which it is reflected. Green, yellow, and orange hues predominate; crimson, violet, and blue are rare, except upon the long and narrow scales that border the suture of the wing-cases, where these colours are the chief reflected."* Mr. Gosse, however, thinks there is some positive colour in their substance.

The scales of fish, the feathers of birds, the hairs of insects, insect-larvæ, and mammalia, will afford you matter for contemplation and study. Scales of fish

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* "Evenings at the Microscope," page 99.

are developed in the substance of the true skin; but those of reptiles, the feathers of birds, the hairs, nails, claws, and horns of mammalia, are developed, not within, but upon the surface of the true skin. The scales of fish are either *ctenoid*, *i.e.*, furnished at their posterior extremities with comb-like teeth, as the scales of the sole; *cycloid*, having scales more or less round, as in the salmon, roach, herring, &c.; *ganoid* (from a Greek word *ganos*, "splendour"), having scales whose substance is essentially bony, hard, and highly polished (this kind has few existing representatives, but numbers are found as fossils); or *placoid*, *i.e.*, having scales separately embedded in the skin, and projecting from its surface in various forms. "In studying the structure of the more highly developed scales, we may take as an illustration that of the *carp*, in which two very distinct layers can be made out by a vertical section, with a third but incomplete layer interposed between them. The outer layer is composed of several concentric laminæ of a structureless transparent substance, like that of cartilage; the outermost of these laminæ is the smallest, and the size of the plates increases progressively from without inwards, so that their margins appear on the surface as a series of concentric lines, and their surfaces are thrown into ridges and furrows which commonly have a radiating direction. The inner layer is composed of numerous laminæ of a fibrous structure, the fibres of each laminæ being inclined at various angles to those of the laminæ above and below it. Between these two layers is interposed a stratum of calcareous concretions, resembling those of the skin of the eel; these are sometimes globular or spheroidal, but more commonly 'lenticula,' that is, having the form of a double-convex lens."* The scales of the eel are con-

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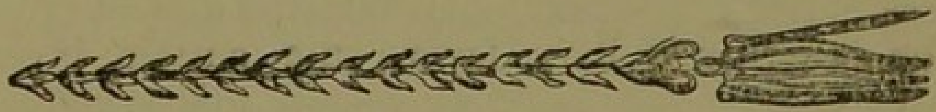
* Dr. Carpenter, page 702.

cealed within the skin; they are oblong in shape, and seem to be composed principally of round calcareous bodies, arranged in many regular concentric series. The scale of the eel is a beautiful object for the polariscope.

If you will pluck a hair out of your head, and hold it between your forefinger and thumb, with the root of the hair upwards, and then move your finger and thumb up and down, you will notice the hair to ascend; now do the same with the root downwards, and the hair descends. How is this? Let us examine its structure under the microscope. Under a magnifying power of about 400 diameters, you will notice that the outer surface of the hair is marked by irregular lines, the indications, as Dr. Carpenter remarks, of the imbricated arrangement of the flattened cells or scales which form the cuticle layer, for all hairs essentially consist of two elementary parts, a *cuticle*, or investing substance, of a dense horny structure, and a *medullary*, or pith-like substance, usually of a much softer texture, occupying the interior. The cuticle part consists of flattened scales arranged in an imbricated manner; the medullary substance is composed of large spheroidal cells. In human hair the cuticle layer is very thin; the medullary portion, which is of a fibrous nature, constitutes the principal part of the shaft of the hair. These fibres may be separated from each other if the specimen be macerated in sulphuric acid for a time, and then crushed between two pieces of glass. Each fibre is a long spindle-shaped cell. The imbricated scales of the cuticle layer may be isolated if the specimen be treated with an acid or an alkali. It is in consequence of the position of these imbricated scales that the upward or downward motion of the hair, when moved between the finger and thumb, takes place, the edges of the scales being arranged in the direction of the apex of the hair. The colour of the hair is due to the presence of pigment-granules and air-cells diffused through its substance. The hairs of bats are very curious; they have projections on their surface, formed by extensions of the scales of the cuticle layer. The hair of a species of Indian bat reminds one of the branch of an equisetum, long, narrow, leaf-like scales being arranged round the shaft in regular whorls. In the mole and other insectivora the cells of the medulla are very distinct. Amongst ruminant animals great variety occurs in the structure of the hair, whilst the camel's hair exhibits pretty nearly the same structure as that of the higher classes. The musk-deer's hair consists almost entirely of the inner medullary layer; the cuticle layer is nearly absent. Nor must we regard this structure of the hair of animals merely as an interesting subject, for as Mr. Gosse has well said, in his charming "Evenings at the Microscope," England's time-honoured manufacture, that which affords the highest seat in her most august assembly, depends on the imbricate surface of hairs. "The hat on your head, the coat on your back, the flannel waistcoat that shields your chest, the double hose that comfort your ankles, the carpet under your feet, and hundreds of other necessaries of life, are what they are because mammalian hairs are covered with sheathing scales.

"It is owing to this structure that those hairs which possess it in an appreciable degree are endowed with the property of *felting;* that is, of being, especially under the combined action of heat, moisture, motion, and pressure, so interlaced and entangled as to become inseparable, and of gradually forming a dense and cloth-like texture. The 'body,' or substance, of the best sort of men's hats is made of lamb's wool and rabbit's fur, not interwoven, but simply beaten, pressed, and worked together between damp cloths. The same property enables woven woollen tissues to become close and thick; every one knows that worsted stockings shrink in their dimensions, but become much thicker and firmer, after they have been worn and washed a little; and the 'stout broadcloth' which has been the characteristic covering of Englishmen for ages, would be but a poor open flimsy texture but for the intimate union of the felted wool-fibres, which accrues from the various processes to which the fabric has been subjected.

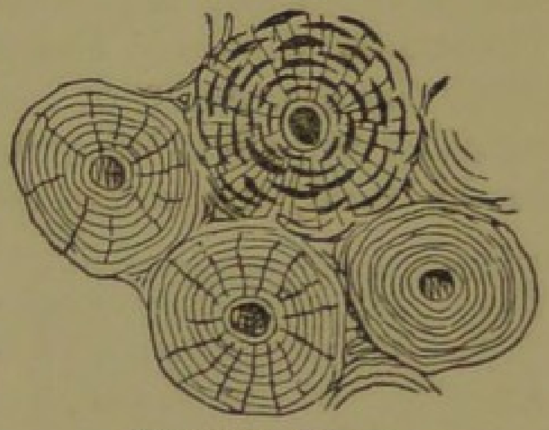
"In a commercial view, the excellence of the wool is tested by the closeness of its imbrication. When first the wool-fibre was submitted to microscopical examination, the experiment was made on a specimen of merino: it presented 2,400 serratures in an inch. Then a fibre of Saxon wool, finer than the former, and known to possess a superior felting power, was tried: there were 2,700 serratures in an inch. Next a specimen of Southdown wool, acknowledged to be inferior to either of the former, was examined, and gave 2,080 serratures. Finally, the Leicester wool, whose felting property is feebler still, yielded only 1,850 serratures per inch. And this connection of good felting quality with the number and sharpness of the sheathing scales is found to be invariable."



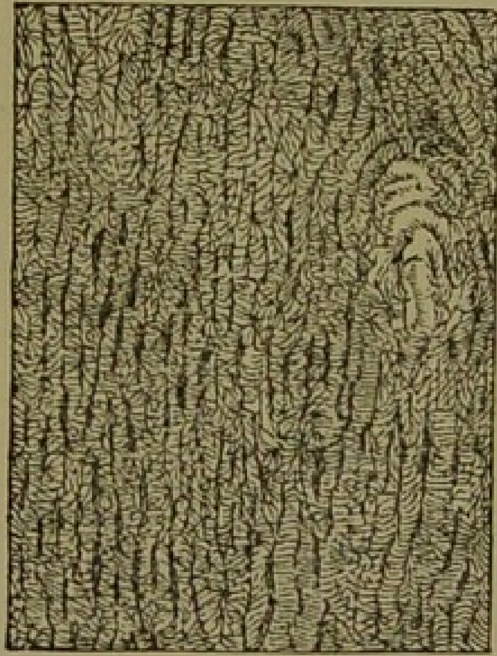
Hair of Larva of Dermestes.

The hairs of insects, caterpillars, &c., are of infinite variety of form. The hairs of the larva of the bacon beetle (*Dermestes*) are of two kinds: in one, the shaft is covered with minute spinous secondary hairs closely packed together; the spines or scales in the others are placed in regular whorls, the highest of which is composed of knobby spines, the whole shaft being "surmounted by a curious circle of six or seven large filaments attached by their pointed ends to its shaft, whilst at their free extremities they dilate into knobs."

I have no doubt that you will find much to occupy your attention, and to afford you delight in the examination of thin sections of bone. "Bone consists of a hard and soft part; the hard is composed of carbonate, phosphate, and fluate of lime, and of carbonate and phosphate of magnesia, deposited in a cartilaginous or other matrix; whilst the soft consists of that matrix, and of the periosteum which invests the outer surface of the bone, and of the medullary membrane which lines its interior or medullary cavity, and is continued into the minutest pores." You can, if you like, prepare the sections of bone for examination, or you can buy specimens already ground and mounted at a small cost. With a thin sharp saw you must make as thin a section as possible, and this must be ground down on a hone, or be rubbed between two smooth hones till you get the desired tenuity. Let the specimen be further polished on a piece of plate glass, in order to obliterate the scratchings caused by the friction on the hone. If it is a long bone you wish to examine, you should make a longitudinal section; if a flat bone, the section should be made parallel to its surface. You will then see it is traversed by a great number of canals, called *Haversian* canals, after their discoverer, Havers. These canals are in connection with the


Structure of Bone.

central cavity, and like it are filled with marrow. By examining a transverse section of a long bone you will see that the small orifices of the canals are in the centre of the layer forming the bone, which is arranged round them in concentric rings; between these layers are small open spaces called *lacunæ*. They are cavities from which the *canaliculi*—extremely minute spider-like tubules, which perforate the bony layers and communicate with the central Haversian canal—proceed. Blood-vessels, from the membrane surrounding the bone termed the *periosteum*, are traceable into the Haversian canals. The *canaliculi* are too small to allow the admission of blood-corpuscles. I may here mention the effect of madder, when given to an animal in its food, upon the osseous system. The bones become coloured with a deep red tinge. The bones of a pigeon were rendered red in about twenty-four hours; it took three weeks to colour the bones of a young pig. Both the external and internal laminæ of the bone are found to be affected by the colouring matter, proving thereby that the action takes place on those parts which lie in contact with blood-vessels.


Section of Humerus of Turtle.

You will be interested to hear that an intimate knowledge of the structure of bone, as acquired by the aid of the microscope, has proved of immense value in determining the tribe of animals to which bones belonged. I shall quote Dr. Carpenter's graphic words: "From the average size and form of the *lacunæ*, their disposition in regard to each other and to the Haversian canals, and the number and course of the *canaliculi*, the nature of even a minute fragment of bone may often be determined with a considerable approach to certainty, as is shown by the following examples, among many which might be cited—Dr. Falconer, the distinguished investigator of the fossil remains of the Himalayan region, and the discoverer of the gigantic fossil tortoise of the Sivalik hills, having met with certain small bones about which he was doubtful, placed them in the hands of Professor Quekett for minute examination; and was informed, on microscopic evidence, that they might certainly be pronounced reptilian, and probably belonged to an animal of the tortoise tribe; and this determination was fully borne out by the evidence, which led Dr. Falconer to conclude they were toe-bones of his great tortoise. Some fragments of bone were found some years since in a chalk-pit, which were considered by Professor Owen to have formed part of the wing-bones of a long-winged sea-bird allied to the albatross. This determination, founded solely on consideration derived from the very imperfectly preserved external forms of these fragments, was called in question by some other palæontologists, who thought it more probable that these bones belonged to a large species of the extinct genus *Pterodactylus*, a flying lizard, whose wing was extended upon a single immensely prolonged digit. No species of Pterodactyle, however, at all comparable to this in dimensions was at that time known; and the characters furnished by the configuration of the bones not being in any degree decisive, the question would have long remained unsettled, had not an appeal been made to the microscopic test. This appeal was so decisive—by showing that the minute structure of the bone in question corresponded exactly with that of the Pterodactyle bone, and differed essentially from that of every known bird—that no one who placed much reliance upon that evidence could entertain the slightest doubt on the matter. By Professor Owen, however, the validity of that evidence was questioned, and the bone was still maintained to be that of a bird; until the question was finally set at rest, and the value of the microscopic test triumphantly confirmed, by the discovery of undoubted Pterodactyle bones of corresponding, and even of greater dimensions, in the same and other chalk quarries."*

CHAPTER IX.

THE MICROSCOPE IN PHYSIOLOGY.

By the aid of the microscope we become acquainted with the wonderful structure of skin and other animal tissues. This figure represents a section of human skin, which is found to consist of two principal layers—the *cutis vera*, or true skin, and the *cuticle*, or *epidermis*, which covers it. A thin vertical section of the skin of the finger shows the upper layer, or *cuticle*, at *a*; the lower part, or *cutis vera*, at *b*; sweat-glands, *e*, with their ducts, at *c*, leading to the orifices; the small granular clusters at *f* are fat-cells; the dull-coloured, wavy portion at *b* is the *rete mucosum*, or *stratum Malpighii*. Mingled with the cells which make up the epidermic covering are found others, which, from their secreting colouring matter, are called pigment-cells. An extraordinary number of blood-vessels, twisting so as to form a complete network of capillaries and numerous nerves, are distributed through the *cutis*

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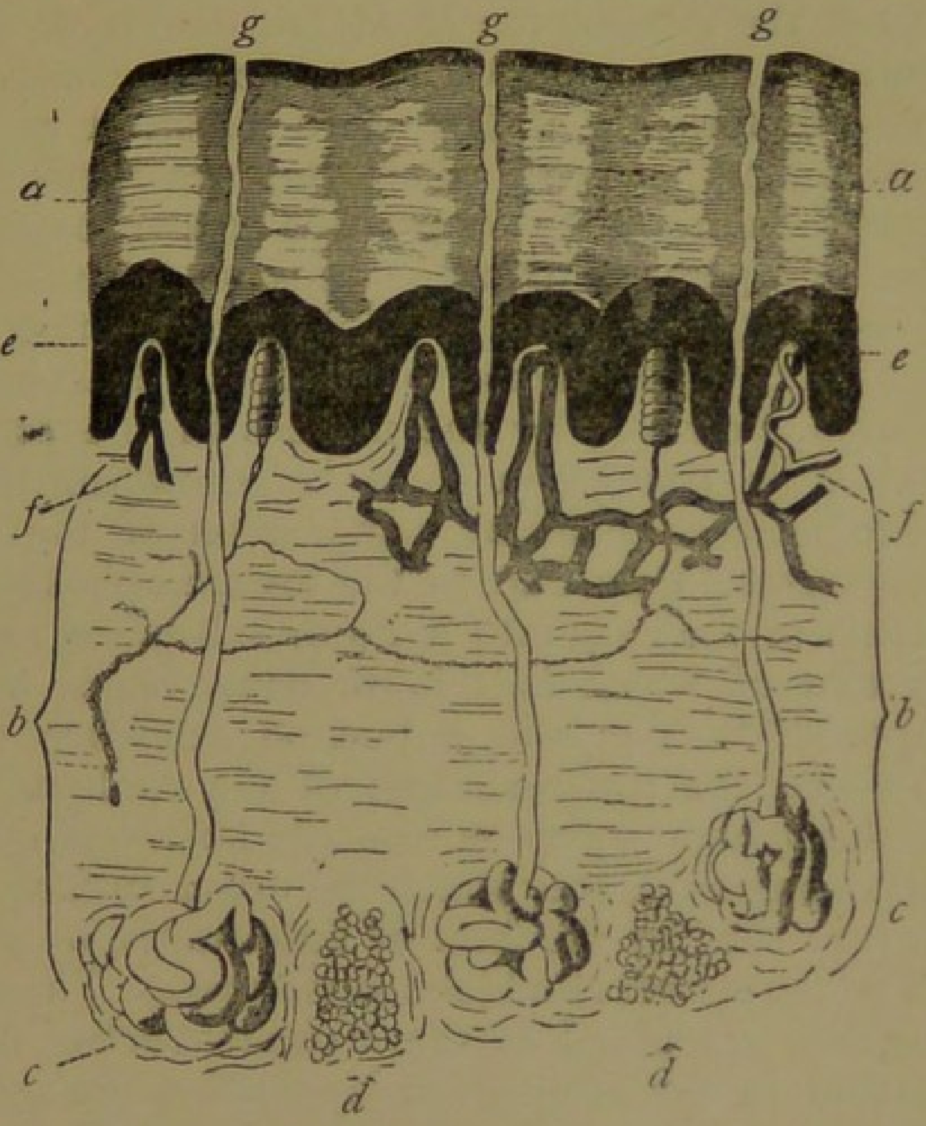
[*] Dr. Carpenter, page 764.

vera, and you know it is impossible to prick any part of your finger with the fine point of a needle without piercing some of these capillaries and drawing blood. The cuticle, or outer covering, is destitute of blood-vessels and nerves; it consists of a series of layers of



cells "that are continually wearing off at their outer surface, and renewed at the surface of the true skin, so that the newest and deeper layers gradually become the oldest and most superficial, and are at last thrown off by desquamation. In their progress from the internal to the external surface of the epidermis, the cells undergo a series of well-marked changes. When we examine the innermost layer, we find it soft and granular, consisting of germinal corpuscles in various stages of development into cells, held together by a tenacious semi-fluid substance. This was formerly considered as a distinct tissue, and was supposed to be the peculiar seat of the colour of the skin; it received the designation of Malpighian layer, or *rete mucosum.* Passing outwards, we find the cells more completely formed; at first nearly spherical in shape, but becoming polygonal where they are flattened one against the other. As we proceed further towards the surface, we perceive that the cells are gradually more and more flattened until they become mere horny scales, their cavity being obliterated; their origin is indicated, however, by the nucleus in the centre of each. This change in form is accompanied by a change in the chemical composition of the tissue, which seems to be due to the metamorphosis of the contents of the cells into a horny substance identical with that of which hair, horn, nails, hoofs, &c., are composed."* You will notice, on reference to the figure, that the lower stratum of the epidermis—*i.e.*, the Malpighian layer—is regularly hollowed out into small depressions, into which the upper surface of the *cutis vera* rises in the form of little ridges, or *papillæ*, from which nerves and blood-vessels arise. The colouring matter contained in the "pigment-cells" is most abundant in the Malpighian layer; they are generally polygonal in form, and contain a number of extremely minute roundish black granules. I have before me a small portion of the dark-coloured vascular membrane of the eye of a sheep, called the *choroid*, and see the numerous cells of the layers of pigment very plainly. In dark-coloured races the pigment cells of the skin

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* Carpenter on the Microscope, p. 718.

are black; in white races they are pink. It is clear that these pigment cells are confined to the cuticle and Malpighian stratum alone; for the *cutis vera* of a negro is as pink as that of the fairer races, so that the colour is not even "skin deep." The subject of epidermic pigment-cells has always appeared to me to be full of deep and curious interest. How are these pigment-cells affected? Why are they black in the negro, olive in the Mongolian, copper-coloured in the North American, pink in the Saxon? Why are they altogether absent in the Malpighian layer of albinoes? The sun would appear to have the power of darkening the pigment-cells, for the exposed parts of a negro are blacker than those which are unexposed. The Jews, moreover, who settled centuries ago in India, "have become as dark as the Hindoos around them." But even in the same individual these epidermic pigment-cells are subject to change. "Can the Ethiopian change his skin?" asks the Hebrew prophet. Cases of such change of colour have occasionally occurred. "One case is that of a negro slave in Kentucky, aged forty-five, who was born of black parents, and was himself perfectly black until twelve years of age. At that time a portion of the skin, an inch wide, encircling the cranium, just within the edge of the hair, gradually changed to white, also the hair occupying that locality. A white spot next appeared near the inner canthus of the left eye; and from this the white colour gradually extended over the face, trunk, and extremities, until it covered the entire surface. The complete change from black to white occupied about ten years; and but for the hair, which was crisped or woolly, no one would have supposed at this time that his progenitors had offered any of the characteristics of the negro, his skin presenting the healthy vascular appearance of that of a fair-complexioned European. When he was about twenty-two years of age, however, dark copper-coloured or brown spots began to appear on the face and hands, but these have remained limited to the portions of the surface exposed to light. About the time that the black colour of the skin began to disappear, he completely lost his sense of smell; and since he has become white, he has had measles and hooping-cough a second time." This occurred in 1852. A case of partial disappearance of the black colour of the negro's skin was brought by Dr. Inman before the Zoological section of the British Association at Liverpool in 1854.*

You notice the perspiratory glands and ducts figured in the engraving at *c* and *g*. By means of these organs a transpiration of fluid holding excrementitious matters in solution takes place. The glands consist of a number of long convoluted tubes, at first dividing into two branches, and then re-uniting into a single tube or duct opening at the surface of the epidermis. The number of these perspiratory pores is enormous. "To arrive at something like an estimate of the value of the perspiratory system," says Mr. Erasmus Wilson, "I counted the perspiratory pores on the palm of the hand, and found 3,528 in a square inch. Now each of these pores being the aperture of a little tube of about a quarter of an inch long, it follows that, in a square inch of skin on the palm of the hand there exists a length of tube equal to 882 inches or 73½ feet. The number of glands in other parts of the body is sometimes greater, sometimes less than this; 2,800 may be taken as the average number of pores in each square inch throughout the body. Now the number of square inches of surface in a man of ordinary stature is about 2,500; the total number of pores,

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* Carpenter's "Principles of Human Physiology," p. 851, note. Sixth Edition.

therefore, may be about *seven millions*, and the length of the perspiratory tubing would thus be 1,570,000 inches, or nearly 28 miles."

I have in a previous chapter called your attention to the circulation of the blood in various animals; the blood itself is an interesting subject for study. Blood consists, in a great measure, of numerous floating cells, called corpuscles. These are of two kinds, the *red* and the *white*. The former are always in the shape of a flattened disc, but they differ in size and configuration In man and in most of the mammalia they are circular; in the camel tribe, however, they are oval, as they are in birds, reptiles, and fishes. In the blood of oviparous vertebrata, the blood-corpuscles have a dark central spot, or *nucleus*, composed apparently of a mass of small granules. If a drop of acetic acid be added to the blood-discs under examination, this will be distinctly seen, the opacity of the nucleus being increased. The average size of human corpuscles has been estimated at about $\frac{1}{3200}$ of an inch in diameter. "The smallest red corpuscles known," says Dr. Carpenter, "are those of the musk-deer, whilst the largest are those of that curious group of batrachian, (frog-like) reptiles which retain their gills through the whole of life; and one of the oval blood-discs of the *Proteus*, being more than thirty times as long and seventeen times as broad as those of the musk-deer, would cover no fewer than 500 of them. According to the recent estimate of Vierordt, a cubic inch of human blood contains upwards of *eighty millions* of red corpuscles, and near a *quarter of a million* of the white."

A small drop of blood should be placed on a glass slide, and carefully protected by a thin glass cover, taking care to exclude air-bubbles; the red corpuscles will be seen, many adhering together like rolls of coins; by gently moving the glass together you will cause them to separate and to roll over. The blood-discs of mammals are entirely destitute of the granular nucleus spoken of above. The discs of the blood-corpuscles of the mammalia are double-concave in form, and the dark spot in the centre is merely an effect of refraction, for by adding a little water to them, they gradually become flat and then double-convex, the dark spot disappearing. They can be made to assume the concave form again by treating them with fluids of greater density than their own contents.

The white corpuscles are much fewer in number than the red, usually not more than as 1 to 350; they are for the most part globular in form, though subject to much variation.

In a medico-legal point of view, it is obvious that a knowledge of the shape and relative sizes of the red corpuscles might be of great use. Suppose, for instance, that a man was brought before the magistrates on a charge of murder; certain marks of blood are found upon his clothes. He insists, it may be, that they are blood-stains of some bird, say a pheasant. The microscope shows the form of the corpuscles to be circular; clearly, then, the stains in question are not those of any bird, which has oval corpuscles. Intimate acquaintance with the forms of the blood-discs of many animals would decide the animal from which they came.

The microscope has been much used in the examination of articles of food and medicine, and has revealed the existence of a great deal of fraudulent practices on the part of unscrupulous tradesmen, who are in the habit of adulterating different productions. "The happy application of the microscope," says Dr. Hassall ("Adulterations Detected in Food and Medicine"), "to the subject of adulteration, has furnished the means of detecting a host of adulterations, the discovery of which had before, for the most part, been considered to be impossible." By means of the microscope, the various forms of cellular and other tissue, starch granules, woody fibres, spiral vessels, &c. &c., are revealed; as the various substances have their distinctive characteristic forms, a mixture of one or more substances with what is sold as a pure and unadulterated substance, becomes evident. The following remarks of Dr. Hassall, one of our highest authorities on food adulteration, will be read with interest:—

"When we survey with our unaided vision any animal or plant, we detect a variety of evidences of organisation or structure; but there is in every part of every animal or vegetable production an extraordinary amount of organisation wholly invisible to the unarmed sight, and which is revealed only to the powers of the microscope. Now this minute and microscopical organisation is different in different parts of the same animal or plant, and different in different animals and plants, so that by means of these differences, rightly understood, the experienced microscopical observer is enabled to identify in many cases infinitely minute portions of animal or vegetable tissues, and to refer them to the parts or species to which they belong.

"Thus by means of the microscope, one kind of root, stem, or leaf may generally be distinguished from another; one kind of starch or flour from another; one seed from another, and so on. In this way, the microscope becomes an invaluable and indispensable aid in the discovery of adulteration.

"Applying the microscope to food, it appears that there is scarcely a vegetable article of consumption, not a liquid, which may not be distinguished by means of that instrument. Further, that all those adulterations of these articles which consist in the addition of other vegetable substances, and which constitute by far the majority of adulterations practised, may likewise be discovered and discriminated by the same means.

"The same remarks apply to all the vegetable drugs, whether roots, barks, seeds, or leaves. We are not acquainted with one such drug which may not be thus distinguished.

"The seeds even belonging to different species of the same genus may frequently be distinguished from each other by the microscope—a point in some cases of very great importance. A remarkable instance of this has fallen under our observation. The seeds of the different species of mustard, rape, &c., may all be distinguished under the microscope by differences in their organisation. To show the importance of the discrimination in some cases, the following instance may be cited. Some cattle were fed with rape-cake, and died with symptoms of inflammation of the stomach and bowels. Nothing of a poisonous nature could be detected on analysis; but it was suspected that the cake might be adulterated with mustard-husk, although even this point could not be clearly established by chemical research. Under these circumstances the cake was sent to the author for examination, who had but little difficulty in ascertaining that it was adulterated with mustard-seed, which, from the large quantity consumed, was doubtless the cause of the fatal inflammation. Not only can the seeds of different plants of the same genus be frequently discriminated by the microscope, but in some cases those belonging even to *mere* varieties of species. The microscope in some cases can even inform us of the processes or agents to which certain vegetable substances have been subjected. Illustrations of this are afforded by the starches of wheat and barley; it can be determined by the microscope whether these are raw baked or boiled, or whether malted or unmalted."*

Cocoa adulterated with Potato Starch.

This figure shows a sample of cocoa adulterated with potato-flower; at *a* you will notice the starch-granules, cells, and spiral vessels of cocoa; at *b* you will see the large characteristic granules of potato-starch.

Milk is a substance very frequently adulterated. "If the testimony of ordinary observers, and even of many scientific writers, is to be credited, there are few

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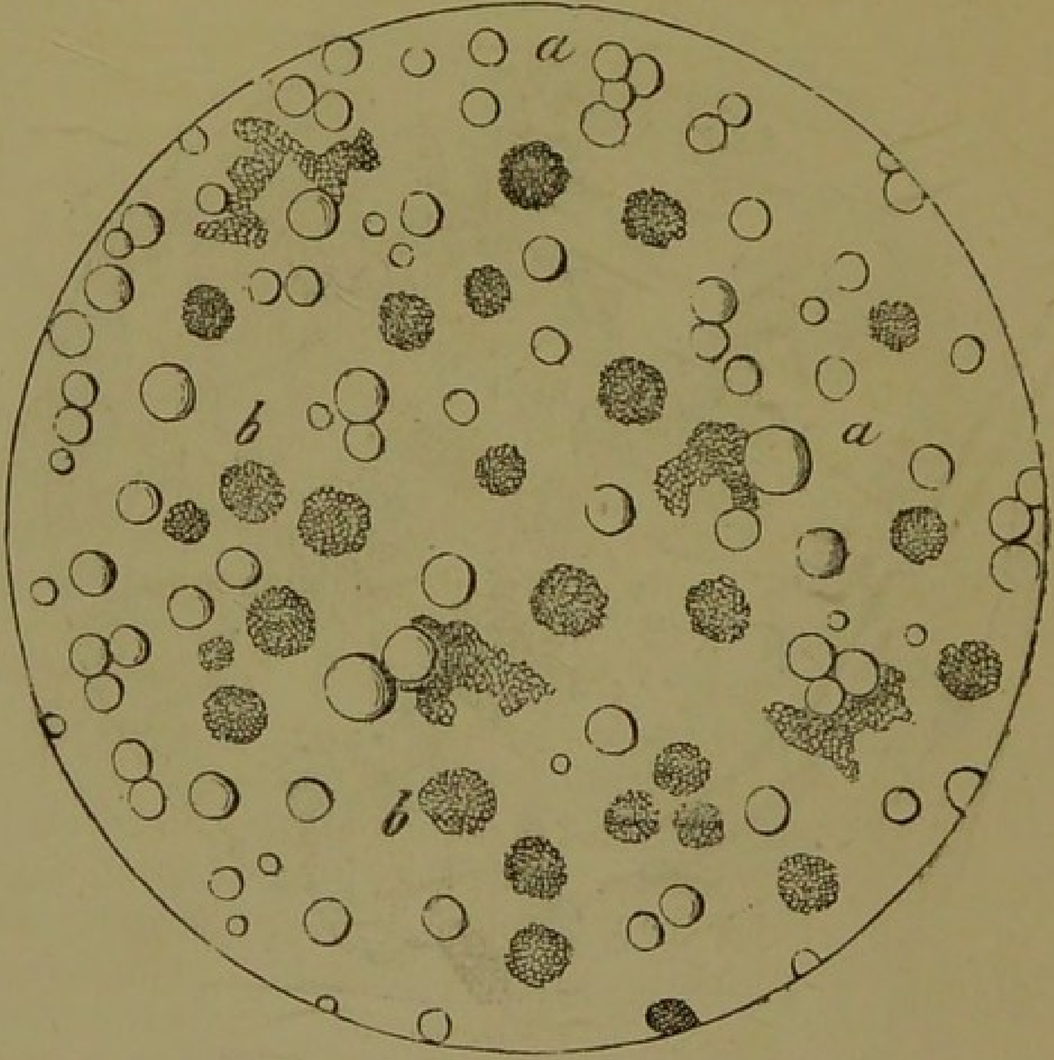
* "Adulterations Detected in Food and Medicine," pp. 44, 45.

articles of food more liable to adulteration—and this of the grossest description—than milk." In a sample of good milk shown below you will observe myriads of beautifully-formed globules of fatty matter, of various size, and reflecting the light strongly. Sometimes the milk is rendered unwholesome from the presence of a number of pus corpuscles, as in the figure; where the fat-globules are few, the milk is poor or deficient in cream, representing the state known popularly known as "skim milk."

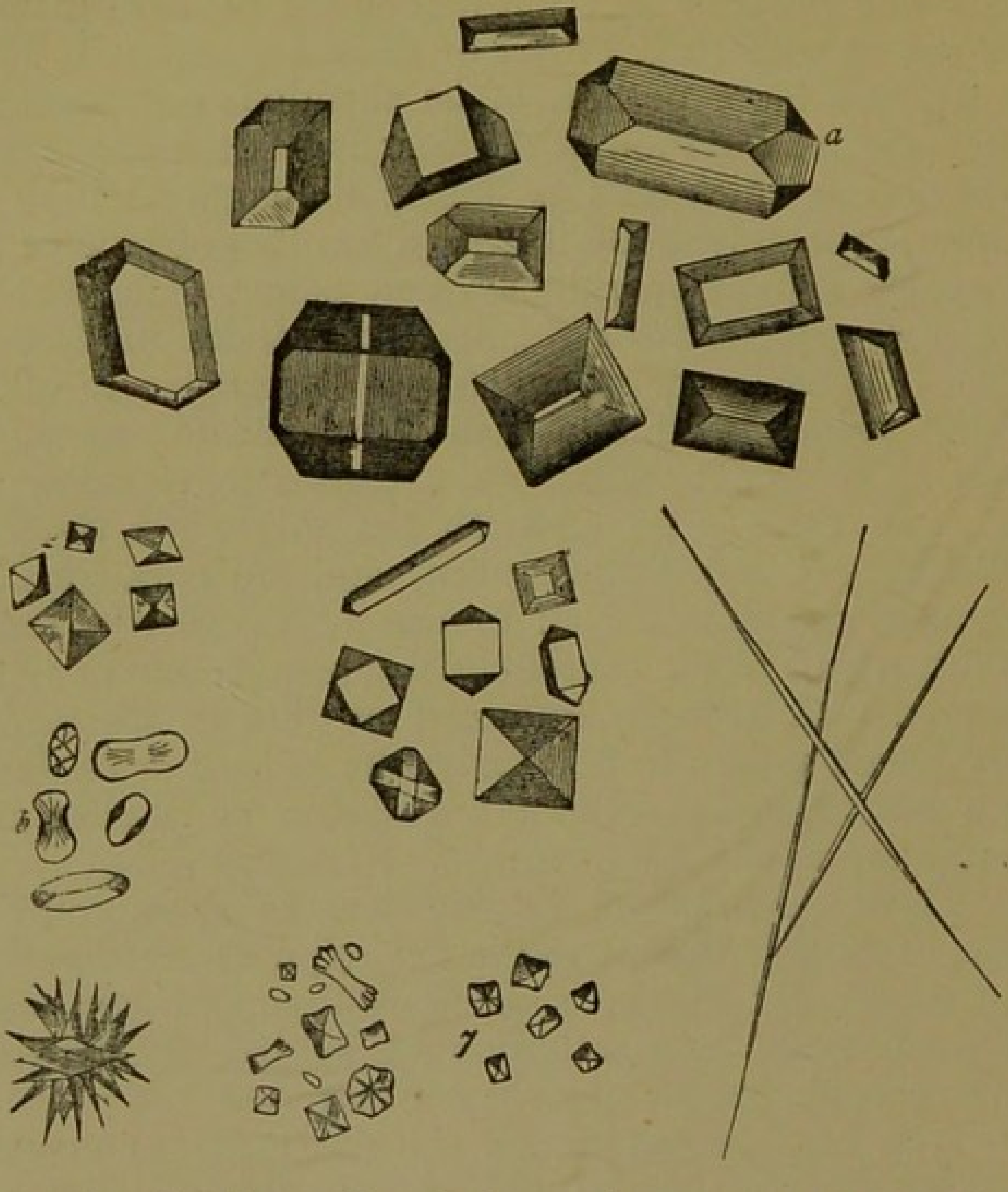


Milk, showing fat-globules (*a*) and pus corpuscles (*b*).

"The most prevalent and important adulteration of milk is that with *water.* Now, some few persons who have not reflected closely upon the matter, may be disposed to make light of the adulteration of milk with water, and to speak in rather facetious terms of the cow with the iron tail; but it is surely no light matter to rob an important article of daily consumption, like milk, of a large portion of its nutritious constituents. But the adulteration with water is not the only adulteration to which milk is liable; the large addition of water frequently made to it so alters its appearance as to cause it to assume the sky-blue colour so familiar to us in our school-boy days, and so reduces its flavour that it becomes necessary to have recourse to other adulterating ingredients—namely, treacle, to sweeten it, salt, to bring out the flavour, and annatto, to colour it. Further, there is no question but that *chalk*, *cerebral matter*, and *starch* have been, and are occasionally, though rarely, employed in the adulteration of milk. With regard to the use of chalk, a manufacturer of preserved milk recently informed us that it sometimes happened to him to find carbonate of lime or chalk at the bottom of the evaporating dishes or pans on the evaporation of large quantities of London milk."

These remarks will be sufficient to show you the use of the microscope in the detection of adulteration in food. Dr. Hassall's book will supply you with abundance of information on the subject, should your microscopic predilections point that way.

It is very curious to see the formation of crystals taking place under the microscope. If you evaporate a solution of common salt on a glass slide, and allow it to cool, and then cover it with a bit of thin glass, you will see some beautiful cubes of chloride of sodium. In the same simple way you may obtain crystals of several salts for examination. On the other side are represented forms of the crystals of ammonio-phosphate of magnesia, the prismatic forms of which are extremely beautiful when viewed with the polariscope (*a*). The other forms depicted are those of oxalate of lime, which, it will be seen, assume various shapes (*b*). When

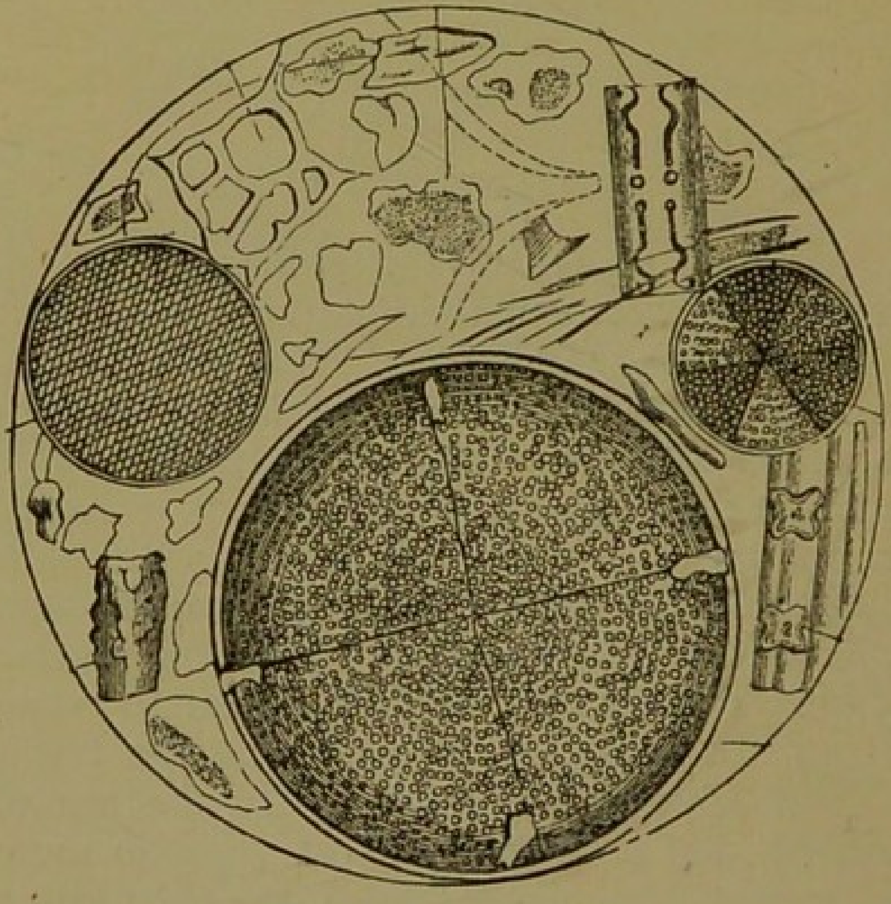


occurring in the cells of plants these crystals are frequently deposited in a needle-shaped form (*raphides*), or they may be rectangular or rhombic prisms with pyramidal ends, often forming groups radiating from a centre. The formation of the crystals of silver is a beautiful thing to see. Place a solution of nitrate of silver on a glass slide, drop a few copper filings upon it; a brilliant arborescent form of crystallisation takes place, growing rapidly as you look at it. This is an interesting case of *affinity*. The nitric acid immediately combines with the copper, and the silver appears in the metallic state.

CHAPTER X.

THE MICROSCOPE IN GEOLOGY.

THE geological student will gather a vast amount of information by means of the microscope. He will be able to determine the nature of the minute animal and vegetable remains that are found in various strata of the earth's crust, as well as the composition of many of the strata themselves. Huge mountains have been shown, by the aid of the microscope, to be composed of countless millions of minute organisms, such as *Diatomaceæ*, *Foraminifera*, &c. "Startling and almost incredible as the assertion may appear to some," as Mr. Hogg truly observes, "it is none the less a fact established beyond all question by the aid of the microscope, that some of our most gigantic mountain ranges, such as the mighty Andes, towering into space 25,250 feet above the level of the sea, their base occupying so vast an area of land, as also our massive limestone rocks, the sand that covers our boundless deserts, and the soil of many of our wide extended plains, are principally composed of portions of invisible animalcules. And, as Dr. Buckland truly observes, 'The remains of such minute animals have added much more to the mass of materials which compose the exterior crust of the globe than the bones of elephants, hippopotami, and whales.'" In some cases these remains consist for the most part of the siliceous shells of the Diatomaceæ, at one time supposed to be of animal origin, but now of undoubted vegetable nature; in other cases, enormous deposits are found to consist principally of the shells of the Foraminifera, minute animals of low organisation. Chalk hills are formed almost entirely of the remains of these little creatures, whose shells are often of most exquisite forms. Ehrenberg has computed that a cubic inch of chalk may contain the remains of a million of these creatures. "The Paris basin, 180 miles long and averaging 90 in breadth, abounds in infusoria and other siliceous remains. Ehrenberg, on examining the immense deposit of mud at the harbour of Wismar, Mecklenburg-Schwerin, found one-



Forms of Diatomaceæ.

tenth to consist of the shells of infusoria, giving a mass of animal remains amounting to 22,885 cubic feet in bulk, and weighing forty tons, as the quantity annually deposited there. How vast, how utterly incomprehensible, then, must be the number of once living beings, whose remains have in the lapse of time accumulated." Richmond, in Virginia, is built upon a stratum, the so-called "infusorial earth," which is eighteen feet thick, and extends over a wide area; this is found to consist principally of the siliceous shells of Diatomaceæ.

The mountain meal (*bergh-mehl*) of Norway, Lapland, Saxony, sometimes forming a stratum nearly thirty feet thick, is similarly composed. Most of these deposits consist of marine forms of Diatomaceæ, but in our own islands, as at Dolgelly in North Wales, Mourne Mountain in Ireland, Mull in Scotland, deposits of fresh-water origin have apparently been formed. In the Foraminifera the skeleton usually consists of a many-chambered calcareous shell investing a jelly-like body; many of these are perforated with numerous little apertures. In the Polycystina, an allied group of the same rhizopod type of animal life, the investing shell is perforated with very large apertures, and it is siliceous; "the apertures are often so large and numerous that the solid portion of the shell forms little more than a network, thus indicating a transition to the succeeding group, the Porifera, or sponges. The Polycystina possess wonderful beauty, and are capital objects for the binocular microscope; its stereoscopic perfection, as Dr. Carpenter remarks, causing them to be presented to the mind's eye in complete relief, so as to bring out, with the most marvellous and beautiful effect, all their delicate sculpture.

The Polycystina are probably as widely diffused as the Foraminifera; they have been brought up by the sounding-lead from the bottom of the Atlantic, at depths of from 1,000 to 2,000 fathoms. We are told that they were probably more abundant during the later geological periods, having been detected by Professor Ehrenberg in the chalks and marls of Sicily and Greece, and of Oran, in Africa, and also in the diatomaceous deposits of Bermuda, and Richmond (Virginia).

"It is an admitted rule in geological science, that the past history of the earth is to be interpreted, so far as may be found possible, by the study of the changes which are still going on. Thus when we meet with an extensive stratum of fossilised Diatomaceæ in what is now dry land, we can entertain no doubt that this siliceous deposit originally accumulated either at the bottom of a fresh-water lake, or beneath the waters of the ocean ; just as such deposits are formed at the present time by the production and death of successive generations of these bodies, whose indestructible casings accumulate in the lapse of ages, so as to form layers whose thickness is only limited by the time during which this process has been in action. In like manner, when we meet with a limestone rock entirely composed of the calcareous shells of Foraminifera, some of them entire, others broken up into minute particles, we interpret the phenomenon by the fact that the dredgings obtained from some parts of the ocean-bottom consist almost entirely of existing Foraminifera, in which entire shells, the animals of which may be yet alive, are mingled with the *débris* of others that have been reduced by the action of the waves to a fragmentary state. Now in the fine white mud which is brought up from almost every part of the sea-bottom of the Levant, where it forms a stratum that is continually undergoing a slow but steady increase in thickness, the microscopic researches of Professor

Williamson have shown that not only are there multitudes of minute remains of living organisms, both animal and vegetable, but that it is entirely, or almost wholly, composed of such remains. Amongst these were about twenty-six species of Diatomaceæ (siliceous), eight species of Foraminifera (calcareous), and a miscellaneous group of objects, consisting of calcareous and siliceous spicules of sponges and Gorgoniæ, and of fragments of the calcareous skeletons of echinoderms and mollusks. The deep-sea soundings which have recently been obtained from various parts of the ocean-bed afford results more or less similar; the *variety* of form, however, usually showing a diminution as the depth increases. From an extensive comparison of the forms of *recent* Foraminifera brought up from different depths, Messrs. Parker and Rupert Jones consider themselves able to predicate the range of depth within which any particular collection may have been taken; and thus to determine, in the case of deposits of *fossil* Foraminifera, within what range of depth they were probably formed."*

Very interesting results have attended the various deep-sea expeditions that have taken place the last few years in different parts of the Atlantic. It has been estimated that nearly two hundredweight of the sea-bottom, revealing, contrary to preconceived notions, a submarine life at a depth of more than 2,000 fathoms, has been dredged up and examined. One of the most curious questions relates to the deposits in the deep water of the Atlantic, and their connection with the Cretaceous period of geologists. For very many years the origin of chalk has been a point of discussion. If you will rub a bit of whiting in a drop of water on a glass side, cover with thin glass, and use a

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* Carpenter on the Microscope, p. 755.

power of 400 or 500 diameters, you will notice a great quantity of rounded flattened bodies. Ehrenberg, I believe, was the first person to observe and describe these little particles. Formerly these bodies were supposed to be mineral concretions of particles derived from organic bodies. They were called crystalloids, and are thus described in the "Micrographic Dictionary," under the word *chalk:* "The cementing material of chalk consists of very minute, numerous, and remarkable bodies, called crystalloids; they are elliptical, or rounded and flattened, from $\frac{1}{10000}$ to $\frac{1}{2500}$ in length, the most numerous perhaps $\frac{1}{3000}$. Some of them consist of a simple ring; in others it is marked with pretty regular transverse lines, so as to make it appear jointed; in others, again, there is a thinner central portion, often exhibiting one or more granules. M. Ehrenberg regards these as arising from the disintegration of the microscopic organism forming the chalk into much more minute calcareous particles, and their reunion into regular elliptical plates (or discs) by a peculiar process, differing essentially from and coarser than that of crystallisation, but comparable with it; one probably preceding all *slow* crystalline formation, and causing, but not alone, the granular state of solid inorganic matter." Recent investigations, however, afforded by the mud, or *ooze*, obtained from the deep sea, have been supposed by some to confirm the opinion, first, I believe, made public by the Rev. J. B. Reade, that these so-called crystalloids are organic. They are now known by the name of coccoliths and coccospheres, and have been found abundantly in the sticky mud of the Atlantic sea-bed. These bodies, be they animal or vegetable, are of extreme low organisation, and are not confined to deep water, for Dr. Wallich has obtained them off the coast of Plymouth at about seventeen fathoms. Whatever be their nature, whether organic or not, it is certain that these bodies abound in extraordinary numbers in chalk and in the *ooze* at the bottom of the Atlantic, and seem to indicate a similar origin and an essential identity of the chalk with modern deep-sea mud. But besides these coccoliths and coccospheres so called, chalk contains other bodies round in form, having many chambers in communion with each other, of microscopic size and beautiful construction. These calcareous bodies are of various forms. Professor Huxley very aptly compares one of the commonest to a badly-grown raspberry, being formed of a number of nearly globular chambers of different sizes congregated together. These bodies have hence been called *Globigerinæ*, and some specimens of chalk consist of little else than Globigerinæ and the granular bodies already mentioned. What a subject for contemplation have we here! Immense chalk cliffs extending for hundreds of miles, the vast fabric the work of minute creatures invisible to the naked eye! In England this chalk formation extends diagonally from Lulworth, in Dorset, to Flamborough Head, in Yorkshire, a distance of over 280 miles as the crow flies. In some places it is more than a thousand feet thick. Nevertheless, as Professor Huxley says, "it covers but an insignificant portion of the whole area occupied by the chalk formation of the globe;" for if all the points at which true chalk occurs were circumscribed, they would lie within an irregular oval about 3,000 miles in long diameter, the area of which would be as great as that of Europe, and would many times exceed that of the largest existing inland sea—the Mediterranean; and all this widespread component of the earth's surface consists for the most part of the skeletons or calcareous shells of Globigerinæ! But recent investigations have shown that the chalk-forming process is even now going on at the bottom of the North Atlantic Ocean over an immense area, and this is brought about for the most part by the same agencies as built up the hills and deposits of the Cretaceous period. This deep-sea mud is substantially chalk, and covers an area of about 1,700 miles from east to west. "It is a prodigious plain—one of the widest and most even plains in the world. If the sea were drained off, you might drive a wagon all the way from Valentia, on the west coast of Ireland, to Trinity Bay, in Newfoundland. And except upon one sharp incline about 200 miles from Valentia, I am not quite sure that it would be necessary to put the skid on, so gentle are the ascents and descents upon that long route. From Valentia the road would lie down-hill for about 200 miles to the point at which the bottom is now covered by 1,700 fathoms of sea-water. Then would come the central plain, more than a thousand miles wide, the inequalities of the surface of which would be hardly perceptible, though the depth of water upon it now varies from 10,000 to 15,000 feet; and there are places in which Mont Blanc might be sunk without showing its peak above the water. Beyond this, the ascent on the American side commences, and gradually leads, for about 300 miles, to the Newfoundland shore.

"Almost the whole of the bottom of this central plain (which extends for many hundred miles in a north and south direction) is covered by a fine mud, which, when brought to the surface, dries into a greyish-white friable substance. You can write with this on a blackboard if you are so inclined, and to the eye it is quite like very soft, greyish chalk. Examined chemically, it proves to be composed almost wholly of carbonate of lime; and if you make a section of it, and view it with the microscope, it presents innumerable Globigerinæ embedded in a granular matrix."* These calcareous shells, which belong to the Foraminiferous group, contain living inhabitants; at least, those which lie on the surface layer of the ooze do, whilst deeper layers are chiefly made up of the empty shells of Globigerinæ. The animal is "a mere particle of living jelly, without defined parts of any kind, without a mouth, nerves, muscles, or distinct organs, and only manifesting its vitality to ordinary observation by thrusting out and retracting, from all parts of its surface, long filamentous processes which serve for arms and legs. Yet this amorphous particle, devoid of everything which in the higher animals we call organs, is capable of feeding, growing, and multiplying; of separating from the ocean the small proportion of carbonate of lime which is dissolved in sea-water; and of building up that substance into a skeleton for itself, according to a pattern which can be imitated by no other known agency." And here I must guard you against Dr. Carpenter's opinion, that the deposit of Globigerina-mud "has been going on over some part or other of the North Atlantic sea-bed from the Cretaceous epoch to the present time—as there is much reason to think that it did elsewhere in anterior geological periods—this mud being not merely *a* chalk formation, but a continuation of *the* chalk formation, so that we may be said to be still living in the Cretaceous period"—an idea which, to use Sir Charles Lyell's words, is as inadmissible in a geographical as a geological sense. You are doubtless familiar with those flinty nodules so extremely abundant in the chalk formation; you are certainly familiar with that common, but very interesting article, a sponge. What connection has the framework of the softest of animals with one of the hardest of stones? The microscope reveals the fact that flint contains

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* Huxley's "Lay Sermons," &c.—"On a Piece of Chalk."

the remains of sponges, for it is not uncommon to find the external forms and markings characteristic of their organisms preserved, whilst thin sections of flint show a spongeous texture in the interior. Foraminiferal shells, and bodies termed *Xanthidia*, with their long spinous projections (the sporangia of Desmidiaceæ), are often found embedded in flint. The siliceous spicules of sponges are also found in jaspers and agates. The pretty little round concretions of the Oolitic formation, so conspicuous in Bath stone, have been formed concentrically round a nucleus which is often a foraminiferal shell. The *green sands* which occur in various deposits from the Silurian to the Tertiary period, and which, when occurring beneath the chalk, are known as the Greensand formation, have been shown by the microscope to consist of the siliceous casts, coloured by silicate of iron, of foraminiferal shells, or those of minute Mollusca. I must not forget to mention the discovery in late years, by Dr. Carpenter, of the nature of the serpentine limestone in the Laurentian formations of Canada. This deposit consists of a regular series of stratified rocks, and underlies the equivalents, not merely of the Silurian, but also of the Upper and Lower Cambrian systems of this country. We are told that these rocks spread over an area of 200,000 square miles, and that they are composed of a species of foraminiferal shell called *Eozoon Canadense.* "The geological position of this fossil, indicating the vast remoteness in time of its existence as a living organism, is scarcely more remarkable than its zoological relations; for at what (so far as we at present know) was the dawn of animal life upon our globe, it affords evidence of a most extraordinary development of that rhizopod type of animal life, which now presents itself only in forms of comparative insignificance, a development which enabled it to separate carbonate of lime from the ocean-waters, in quantity sufficient to produce masses rivalling in bulk and solidity those of the stony corals of later epochs, and thus to furnish (as there seems good reason to believe) the materials of those calcareous strata, of whose occurrence in the Laurentian series it had previously been impossible to give a satisfactory account."* Wonderful, truly, it is to reflect that such enormous results are brought about by the operations of an animal of such extreme simplicity. These rhizopods seem to have performed in the seas of the Laurentian epoch the same part in the production of limestone rocks which was subsequently taken by coral polypes, echinoderms, and mollusks, as well as by minuter forms of Foraminifera; "and it is a fact not without an important significance," Dr. Carpenter also remarks, "that this the lowest type of animal life known to the physiologist, should have thus culminated in the very earliest period in the history of the life of our globe with which the palæontologist is at present acquainted. . . . . The physiologist has here a case in which those vital operations which he is accustomed to see carried on by an elaborate apparatus, are performed without any special instruments whatever—a little particle of apparently homogeneous jelly, changing itself into a greater variety of forms than the fabled Proteus, laying hold of its food without members, swallowing it without a mouth, digesting it without a stomach, appropriating its nutritious material without absorbent vessels or a circulating system, moving its parts without muscles, feeling (if it has any power to do so) without nerves, propagating itself without a genital apparatus, and forming a shelly covering that possesses a symmetry and complexity not surpassed by those of any testaceous animals."†

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* Dr. Carpenter in *Intellectual Observer*, vii. 278.

† Introduction to the Study of the Foraminifera. Ray Society, p. vii.

CHAPTER XI.

THE MICROSCOPE IN GEOLOGY (*continued*).

It has long been suspected that the extremely useful substance called coal is nothing else than a consolidated mass of decomposed vegetable matter; it is not, indeed, uncommon to find certain markings or indications of a vegetable origin in a lump of coal, and the microscope has enabled us to determine the nature of that vegetation by revealing its structure. It shows us that the coal vegetation was in a great measure coniferous in its nature, "that it probably approximated most nearly to that group of existing Coniferæ to which the Araucaria belong." It is one characteristic of coniferous wood to exhibit a number of glandular dots on the woody fibres; now these glandular dots are often to be seen in sections of coal. Owing to the extreme friability of coal, its examination is attended with some difficulty, for it is no easy matter to reduce slices to the necessary degree of tenuity. The following mode of examining the structure of coal is taken from the "Micrographic Dictionary:"—"The coal is macerated for about a week in a solution of carbonate of potash; at the end of that time it is possible to cut tolerably thin slices with a razor. These slices are then placed in a watch-glass with strong nitric acid, covered, and gently heated; they soon turn brownish, then yellow, when the process must be arrested by dipping the whole into a saucer of cold water, or else the coal would be dissolved. The slices thus treated appear of a darkish amber colour, very transparent, and exhibit the structure when existing most clearly. The specimens are best preserved in glycerine, in cells; we find that spirits render them opaque, and even Canada balsam has the same effect."

Mr. David Forbes, in a very interesting paper—"The Microscope in Geology"—in the *Popular Science Review* for October, 1867, has shown how much may be learnt of the mineral composition of rocks by a careful and patient use of the microscope. Previous to Mr. David Forbes' application of the microscope to determine the composition of rocks, very little appears to have been done, with the exception of Mr. Sorby's memoirs on such special points of inquiry. Mr. David Forbes' collection of sections of rocks and their constituent minerals were, for the most part, made by himself; it amounted, in 1867, to upwards of 2,000, and represents a wide geographical distribution. "As long as the geologist encounters in the field any rocks of so coarse or simple a structure as to admit of their being resolved by the naked eye into their constituent mineral species, or of distinguishing the fragments of previously existing rocks, of which they may have been built up, he may speculate with a fair chance of success as to their probable origin or mode of formation. When, however, as is often more the rule than the exception, rocks are everywhere met with presenting so fine-grained and apparently homogeneous a texture as to defy such attempts at ocular analysis, all speculations as to their nature and formation, based merely upon observation in the field, can but be compared to groping in the dark, with the faint hope of stumbling upon the truth.

"In these cases the geologist must call in the aid of chemistry and the microscope; by chemical analysis he learns the per-centage composition of the rock in question, and the microscopic examination informs him how the chemical elements are mineralogically combined, and at the same time affords valuable information as to the physical structure and arrangement of the components of the rock mass, tending to elucidate its formation and origin." Let me select one or two instances out of several given by Mr. D. Forbes. You are, perhaps, acquainted with the mineral termed *Obsidian*, or *Volcanic glass*, which is produced by the fusion of felspathic rocks or those which contain alkaline silicates. The glassy appearance testifying to an apparently complete vitreous condition would, at first sight, defy all attempts to discover the structure; nevertheless, some part of the mass will be found to be sufficiently devitrified to allow of its structure and mineral composition being recognised, and Mr. D. Forbes has figured a very pretty section of obsidian in which the pyroscenic and felspathic constituents of the rock are very clearly apparent. Rocks, according to their structure, fall naturally into one or other of two great classes—(1) *Primary*, or *Eruptive;* and (2) *Secondary*, or *Sedimentary*. Now, in some cases it is impossible to determine by mere ocular inspection to which of these classes a certain rock may belong. Microscopic examination shows that whatever be the geological age of these primary rocks, or from whatever part of the earth's surface they may be taken, they "possess certain general and definite structural characters distinguishing them at once from all other rocks."

There occurs, either found embedded in or breaking through the coal-measures of Staffordshire, a rock popularly termed "White Horse," from often having the appearance of a whitish clay; the coal-measures at points of contact with the rock are frequently burnt and altered. "The origin of this rock, whether sedimentary or igneous, was disputed until the more recent geological and chemical examinations of it have proved satisfactorily its identity with the Rowley basaltic rock." In external appearance, the mineral uralite resembles augite, but its chemical composition is that of hornblende; the microscope distinctly reveals the fibrous structure characteristic of the hornblende.

Some years ago, you may remember, a geological heresy was maintained by some, that granite had not, after all that had been said, an igneous origin. Let us see what part the microscope played in determining the question. Mr. Sorby discovered in the quartz of granites numerous minute fluid cavities, thus showing that granites have solidified at a heat far below the fusing points of their constituent minerals, and at such a pressure as to enable it to entangle and retain a small amount of aqueous vapour, which naturally must have been present during its liquefaction. "The presence of these fluid cavities in the quartz of granite was immediately blazoned forth as proof positive of the non-igneous origin of granite; whereas, if Mr. Sorby's memoir had actually been read, it would have been seen that he had found fluid cavities perfectly identical with those of granite, not only in the quartz of volcanic rocks, but also in the felspar and nepheline ejected from the crater of Vesuvius; and that the presence of fluid, vapour, gas, and stone cavities are common both to the volcanic quartz-trachytes and to the oldest granites; and the inference drawn by Mr. Sorby from the results of his researches, is that both these rocks were formed by identical agencies." As with regard to the volcanic, so with the sedimentary rocks; a microscopic examination alone will afford correct information as to their origin; but I must refer you to Mr. David Forbes' most interesting memoir for further details. Mr. D. Forbes gives the following instructions how to prepare rock sections:—"A fragment, from one quarter to three-quarters of an inch square, and of convenient thickness, is chipped off the rock specimen in the direction of the required section, and ground down upon an iron or pewter plate in a lapidary's lathe, with emery, until a perfectly flat surface is obtained. This surface is then worked down still finer by hand on a slab of black marble, with less coarse emery; then upon a Water of Ayr stone, with water alone, and lastly finished by hand with water on a slab of black marble. By these means the surface acquires a sufficient polish, without being contaminated with rouge or other polishing-powder or oil, as is sometimes the case with purchased sections of rocks. This side of the rock is now cemented by Canada balsam on to a small piece of plate glass, about 1½ in. square, and ⅜ in. thick, which serves as a handle when grinding the other side on the emery plate as before. This grinding is continued until the section is so thin as to be in danger of breaking up from the roughness of the motion, upon which it is completed, by further grinding with emery by hand on marble, and finished first upon Water of Ayr stone with water, and afterwards upon black marble, as before described. The section is now removed from the plate glass, and mounted in Canada balsam on a slide, covering its upper surface with a thin glass as usual."

By the aid of the microscope the geological investigator is able to ascertain the nature, and even to construct the entire form of an animal long ago extinct, by the examination of minute parts that have been preserved in the tomb of the earth. Fossil corals, fragments of the shells or spines of Echinodermata, and of such molluscous shells as present distinct appearances of structure, may be identified by its means. A knowledge of the structure of teeth, bones, the dermal skeleton of vertebrate animals, will enable the microscopist to name the animal to which the parts belonged. You are, of course, aware that the different strata are more or less characterised by the organic remains which they contain. In some cases the strata may be so similar in composition, that it is impossible to determine its position on the geological chart in the absence of organic remains. Many thousand pounds would have been saved to the pockets of certain land proprietors had they consulted the geologist or microscopist before they sank shafts for coal in beds which could not possibly contain any. Extending over many parts of Russia, there occurs a certain rock formation, whose mineral characters might justify its being likened either to the *Old* or *New* Red Sandstone of this country, and whose position relatively to other strata is such, that there is great difficulty in obtaining evidence from the usual sources as to its place in the series. The nature of this formation could be determined by the organic remains which it might yield, but in this case they were few and fragmentary, and consisted chiefly of teeth which were seldom found entire. It was at first supposed from the great size of these teeth, that they belonged to Saurian reptiles; hence the formation must have been considered New Red. External form may be deceptive; so recourse was had to a microscopic section of the tooth, the result of which was to show that it belonged to an undoubted fish, called, from the dendritic disposition of the tissues, by the name of *Dendrodus*. This decided the all-important point, for as the genus *Dendrodus* is exclusively Palæozoic, the rock in question belonged not to the New, but to the Old Red formation; therefore there would be no possibility of finding coal in it.

You will be interested in another similar case. The identity of the Keuper Sandstein of Wirtemburg, with the New Red Sandstone of Warwickshire, has been satisfactorily demonstrated by means of the microscope. Some years ago, Professor Jaeger found in the German Keuper formation some remarkable fossil teeth, which were of great size, conical or canine in form, and distinctly striated. In 1840 Professor Owen found similar teeth in the New Red Sandstone of Coton End quarry, Warwickshire. What was the nature of the animal to which these teeth belonged? From external characters it had at first been inferred that the teeth were those of some Saurian reptile; but the results of a microscopic examination of the teeth, both from the German Keuper and the New Red Sandstone of Warwickshire, revealed a very remarkable and complicated structure; hence, provisionally, the creature to which the teeth were supposed to belong was named *Labyrinthodon*, by Professor Owen; but this peculiar internal structure of the tooth—a structure formed by "the convergence of numerous inflected folds of the external layer of cement towards the pulp cavity"—is typically presented also in the teeth of fish-lizards and lizard-like fish; hence it might be reasonably inferred that the labyrinthodon would combine with its reptilian characters an affinity with fish. The subsequent discovery of some of the bones of the labyrinthodon, as the vertebræ, jaws, humerus, femur, and toes, &c., have gone far to establish this inference; and there is much reason to believe that that strange creature, the labyrinthodon, was a gigantic frog-like animal five or six feet long, with a mixture of fish and crocodilian characters, and that in all probability it was identical with the animal whose footprints have been discovered in the quarries of the grey quartzose and red sandstone of Saxony, and in the sandstone quarries of Stourton, in Cheshire.

CHAPTER XII.

THE COLLECTION AND MOUNTING OF OBJECTS—TEST-FLUIDS.

THERE is little need that I should say much on the collection of objects you may wish to examine; a little experience will prove the best instructor. If you wish to collect Desmidiaceæ and Diatomaceæ, you should take with you two or three wide-mouthed bottles with corks, a tin scoop, a sharp hook for cutting off stems of aquatic plants, which are often covered with minute vegetable organisms (these two last should be made to screw on to a long light bamboo rod), and a lens. The Desmidiaceæ occur in slow-running rivers, pools, ditches, especially those on boggy moors. They often form a greenish cloud on the stems and leaves of water-plants, or on the ground. They may be taken up from the ground by the scoop, or from the stems of plants by your fingers. If placed in bottles and exposed to the light, these vegetable forms will grow, and you may employ your time advantageously in studying the development. Diatomaceæ are also found in profusion on the stems and leaves of aquatic plants, presenting themselves as coloured fringes, or forming a covering to stones or rocks in cushion-like tufts, or spread over their surface as delicate velvet, or depositing themselves as a filmy stratum on the mud, or intermixed with the scum of living or decayed vegetation on the surface of the water. They are often mixed with sand and mud; and the best way to get rid of these impurities is to place the lot in a saucer of water, and expose it to the light, when the diatoms may be skimmed from the surface. Various beautiful forms occur upon sea-weeds, and on the mud at the bottom of the sea. You may also procure numerous forms from the stomach of various sea-creatures, such as oysters, sea-cucumbers, sea-squirts, soles, and other flat-fish. It is a distinctive character of this group to have encircling their various forms an external coat of silex, which would appear to be almost indestructible. We have seen how an accumulation of them give rise to deposits of considerable thickness; and guano, it is well known, contains many forms, some of extreme beauty. If you wish to collect Diatomaceæ from guano, you should wash a portion several times in water, and stir it well; then let it rest for some hours, so as to give the lighter forms time to sink; then pour off the water, and if necessary give the sediment another washing. You must now use strong acids; the deposit is to be placed in a test-tube with hydrochloric acid, and gently heated. After the sediment has subsided, pour off the acid, and heat it with a fresh dose; pour off again, and heat with nitric acid two or three times, and apply heat for three or four hours of about 200°; then wash the sediment till the acid is removed. "The separation of siliceous sand, and the subdivision of the entire aggregate of diatoms into the larger and the finer kinds, may be accomplished by stirring the sediment in a tall jar of water, and then, while it is still in motion, pouring off the supernatant fluid as soon as the coarser particles have subsided; this fluid should be set aside, and as soon as a finer sediment has subsided, it should again be poured off; and this process may be repeated three or four times at increasing intervals, until no further sediment subsides after the lapse of half an hour. The first sediment will probably contain all the sandy particles, with perhaps some of the largest diatoms, which may be picked out from among them;

and the subsequent sediments will consist almost exclusively of diatoms, the sizes of which will be so graduated that the earliest sediments may be examined with the low powers, the next with the medium powers, while the latest will require the higher powers—a separation which is attended with great convenience;"* small portions of the sediment should then be mounted in Canada balsam, or set up dry between two pieces of thin glass. For mounting microscopic objects you will require a pair of fine-pointed forceps for holding the objects to be mounted, a pair of stout needles fixed in handles, a spring clip† for holding down the covers whilst the balsam is cooling, and a small spirit-lamp.

Canada balsam—a natural combination of resin with the essential oil of turpentine—may be procured from any druggist. It is thick and viscid, but becomes softer on the application of heat; you must be careful to keep it very clean and to exclude the air, which would render it too thick for immediate use. To mount in Canada balsam, place a drop on the glass slide by means of a glass rod, then apply gentle heat, immerse the object in it, and if there are no air-bubbles, place the glass cover on, apply the spring clip, and set aside for the balsam to harden. You will, however, have need to exercise much patience; for no sooner is the object placed in the balsam than all at once many air-bubbles make their unwelcome appearance; you must, therefore, boil the balsam over the spirit-lamp, if the texture of your object will allow you to do so, and the heat will probably drive out the intruding bubbles. It is advisable to prepare some objects before mounting in Canada balsam by soaking in oil of turpentine for some minutes. Insect

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* Carpenter, page 315.

† Sold by Messrs. Baker, Mr. Collins, and others.

structures, Foraminifera, &c., may be thus treated; the oil of turpentine entering into the cavities or tissues, excludes the air.

Spirit and distilled water form an excellent medium for preserving animal tissues; one part of alcohol, 60 over proof, to five parts of distilled water, will be found of sufficient strength for preserving many substances. Methylated alcohol, which pays no duty, answers very well, and it may be obtained at the price of five shillings and sixpence per gallon. A drop of this dilute alcohol is to be placed, by means of a glass rod, on the glass slide, the tissue is to be sunk into it, and covered with thin glass; care must be taken to exclude air-bubbles, the superfluous fluid drained off, and the edge of the glass cover and adjacent portion of the slide wiped quite dry. A ring of cement—gold size may be especially recommended—is to be laid round the edge of the thin glass, so as to fix the cover on the slide. After this coating has hardened, apply a second and a third.

A solution of glycerine with camphor-water is another valuable fluid for preserving structures. Price's glycerine is superior to any other for microscopic purposes. The proportion of glycerine and camphor-water will depend on the nature of the object to be mounted; for general purposes, one part of glycerine to two parts of camphor-water will be found useful. There are various other preservative fluids and cements which are very useful in microscopic work, but those I have named will be sufficient for most practical purposes.

Test-liquids are of immense use to the microscopist; they are employed to remove certain substances which he wishes to get rid of, or to detect the presence of particular substances in the object under examination. For instance, suppose I wish to obtain the animal basis of a bone or shell, I must dissolve the calcareous portions by means of a mixture of hydrochloric and nitric acid; if I wish to get rid of the organic matter in sponges, so as to obtain the mineral portion in a separate state, I can do so by boiling the objects in a solution of caustic potash; if it is desirable to harden animal tissues, this can be done by maceration in strong alcohol, or in a solution of chromic acid, "so dilute as to be of a pale straw colour, which is particularly efficacious in bringing into view the finer ramification of nerves." If, on the other hand, I wish to detect the presence of some particular substance in the object I am examining—say of starch granules—I apply a solution of iodine in water (1 gr. of iodine, 3 grs. of iodide of potassium, 1 oz. of distilled water), and the starch is turned blue; if albuminous substance is present, the test gives it an intense brown. Acid nitrate of mercury colours albuminous substances red. A solution of caustic potash or soda, by means of its solvent power, is extremely useful in rendering animal and vegetable structures transparent. If you wish to clean any glass slides or covers, and to get rid of the Canada balsam or cement, you can readily do by means of spirits of turpentine.

I shall conclude this very imperfect sketch of some of the marvels of the microscope by quoting some very valuable words of advice of an eminent microscopist, Dr. Lionel S. Beale, F.R.S.:—

"No one engaged in the pursuit of any branch of natural science is more tempted to be led into too hasty generalisation than the microscopic observer. It is his duty, therefore, to avoid drawing inferences until he has accumulated a vast number of facts to support the conclusions at which he has arrived. True generalisations and correct inferences promote the rapid advancement of scientific knowledge, for each new inference may form the starting-point of a fresh line of investigation; but, on the other hand, every false statement, regarded as an observed fact, forms a terrible barrier to onward progress, since, before the slightest useful advance can be made, it is necessary to retrace our steps, it may be for a long way, before we can hope to recommence our onward course. Again, a much greater amount of evidence is always required to overthrow a false conclusion than is sufficient to propagate the original mistake, and there can be no task more unsatisfactory than that of being called upon to controvert the opinions and deductions of others. Years must be passed in patient investigation before a man can expect to be able to trust himself as an observer of facts, and it is only by careful and unremitting exercise that he will gradually acquire habits of attentive observation and the power of thoughtful discrimination, which can alone render his conclusions reliable. Indeed, though he labour hard and earnestly, he will scarcely have properly educated himself ere his powers begin to decay, and he become liable to err from the natural deterioration in structure of the organs upon which the observation of his facts entirely depends."

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* "How to Work with the Microscope," Fourth Edition, pp. 188, 189.

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