THE

BOTANIST'S COMPANION

OR

DIRECTIONS FOR THE USE OF THE MICROSCOPE,
AND FOR THE COLLECTION AND
PRESERVATION OF PLANTS,

WITH A

GLOSSARY OF BOTANICAL TERMS.

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PREFACE.

THE object of the present brochure is to aid the student in the use of the Microscope, and in the prosecution of Vegetable Histology; to direct him as to the mode of collecting and drying plants, and of forming a Herbarium; to give useful hints in regard to botanical excursions; and to furnish explanations of the more important terms employed in botanical works.

It is compiled partly from the edition of the Author's Manual of Botany for 1860, and partly from the Appendix to his Class Book of Botany; and it is intended to be a pocket companion to the student in his practical researches. The Microscope has become such an essential instrument in the prosecution of Botany, that it is necessary to acquire a thorough knowledge of its use, and to understand the errors which may arise from unguarded observation. The formation of a Herbarium is also required in the study of classification, and in the diagnosis of genera and species; while the proper understanding of botanical terms and a correct nomenclature form the basis of descriptive Botany. The accurate definition of technical terms is an important part of scientific study. In mastering these terms, the student acquires, as it were, the alphabet of the science, without a thorough knowledge of which he cannot be expected to make progress.

EDINBURGH, *April* 1860.

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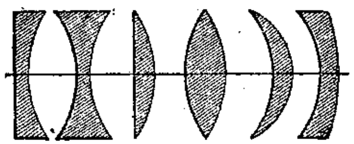
I.—On the Use of the Microscope in Botanical Researches.

The Microscope is a most important instrument in education, and it is essential for the due understanding of the structure and physiology of plants. The study of the microscopical structure of organized bodies is termed *Histology* (ἱστὸς, a web or tissue, and λόγος, discourse). Dr. Carpenter remarks:—"The universe which the microscope brings under our ken, seems as unbounded in its limit as that whose remotest depths the telescope still vainly attempts to fathom. Wonders as great are disclosed in a speck, of whose minuteness the mind can scarcely form any distinct conception, as in the most mysterious of those nebulæ, whose incalculable distance baffles our hopes of attaining a more minute knowledge of their constitution. And the general doctrines to which the labours of microscopists are manifestly tending, in regard to the laws of organization and the nature of vital action, seem fully deserving to take rank in comprehensiveness and importance with the highest principles yet attained in physical or chemical science. It is by pursuing, by the aid which the microscope alone can afford to his visual power, the history of the organic germ, from the simple and homogeneous form which seems common to every kind of living being,—either to that complex and most heterogeneous organism which is the mortal tenement of man's immortal spirit, or only to that humble Protophyte or Protozoon, which lives, and grows, and multiplies, without showing any essential advance upon its embryonic type, that the physiologist is led to the grandest conception of the unity and all-comprehensive nature of that creative design, of which the development of every individual organism, from the lowest to the highest, is a separate exemplification, at once perfect in itself, and harmonious with every other."

The microscope (μικρὸς, small, and σκοπέω, I see) is an instrument for enabling the eye to see distinctly objects which are placed at a very short distance from it, or to see minute objects that would otherwise be invisible. It has been used with great success in the examination of vegetable structure. To it we are indebted for a knowledge of the various vessels and cells which enter into the composition of the different parts of plants, of the circulation of fluids, and of ciliary movements, as well as for the facts connected with the development of the embryo. It is an instrument, however, which requires to be used cautiously; and the conclusions drawn from it ought to be carefully weighed, more especially when the observations have been made with high magnifying powers.

LENSES.—Before proceeding to notice the construction of simple and compound microscopes, it will be advantageous to notice the different kinds of lenses used, and the sources of error which require to be guarded against in their preparation. The chief forms of lenses used are, the *double-convex* (fig. 4), with two convex faces; *plano-convex* (fig. 3), with one face flat and the other convex; *double-concave* (fig. 2), with two concave faces; and *plano-concave* (fig. 1), with one flat and one concave face. Sometimes, also, a *meniscus* (fig. 5) is used, with a concave and a convex face, and a sharp edge, and a *concavo-convex* (fig. 6), with a concave and convex surface and flat edges. Convex lenses with sharp edges cause parallel rays to converge; while concave lenses with flat edges cause them to diverge. The lenses used in microscopes are chiefly convex,—the concave lenses being employed to make certain modifications in the course of the rays passing through convex lenses, whereby their performance is rendered more exact. The magnifying power of a single lens is its focal length. The principal focus is



1, 2, 3, 4, 5, 6.

Figs. 1-6. Different kinds of lenses—1. Plano-concave. 2. Double concave. 3. Plano-convex. 4. Double convex. 5. Meniscus. 6. Concavo-convex. 3, 4, 5, are sharp-edged lenses, and cause convergence. 1, 2, 6, are flat-edged, and cause divergence.

the point to which parallel rays converge after reflection or refraction. The focus of a double convex lens is at half the distance of a plano-convex, having the same curvature on one side. Ten inches is the mean focal length of the human eye. In the use of ordinary lenses, there are sources of error from the form of the lens, and the nature of the material of which it is made. When parallel rays fall on a double-convex or a plano-convex lens, they are brought into a focus at a certain distance: but it is found that no lens with a spherical surface can bring the rays of light coming from one point exactly into the focus at another point. Hence arises what is called *spherical aberration*. In this kind of aberration, the objects at the circumference of the field of the microscope are not in focus at the same time as those in the centre. Moreover, the material of which the lens is made acts differently on the different portions of each ray, and separates the white light into different colours, which have various degrees of refrangibility. This gives rise to *chromatic* (χρῶμα, colour) *aberration*. To remedy these defects, certain combinations of glasses have been adopted, so that the light traversing one lens through the centre may pass through near the margin of another. The confusion produced by these aberrations may be greatly lessened by diminishing the pencil of light; for instance, by employing a stop or diaphragm, which lessens the aperture of the lens, and cuts off the peripheral rays. In lenses of low power, such as are used in the simple dissecting microscope, these aberrations will not cause much confusion. It is only when high powers are required that these aberrations must be done away with,—the aperture being increased without interfering with definition. The invention of Wollaston's doublet with two lenses, and Holland's triplet with three, was with the view of diminishing, as far as possible, these aberrations. In this, however, they were not successful, for coloured images were still produced. Their lenses were constructed of the same kind of material; and it was afterwards found that in order that lenses might present the object uncoloured, or be what is called *achromatic* (α, privative, and χρῶμα, colour), it was necessary to use glasses of two different densities. Achromatic lenses, or such as are nearly free from aberration, are constructed by placing together glasses of different dispersive powers, and of different forms. The usual achromatic consists of a double-convex lens, made of plate or crown-glass, and a plano-concave, made of flint-glass (fig. 7), fitted accurately to it, and cemented by Canada balsam. Sometimes three lenses are used, a double concave of flint-glass, placed between two double convex of crown-glass, and ground to certain curvatures; and in that case they cannot be cemented. The most perfect combination of lenses, for high powers, consists of eight distinct lenses:—In front, a triplet of two plano-convex lenses of crown-glass, with a plano-concave of dense flint-glass between them; next, a doublet composed of a double convex lens of crown-glass, and a double concave of flint; and at the back, another triplet of two double convex lenses of crown, with a double concave of flint between them. By this combination, an angular aperture of 170° has been obtained with an objective of $\frac{1}{12}$th of an inch focus. This is about the limit; for 10° more would bring the rays to a straight line.

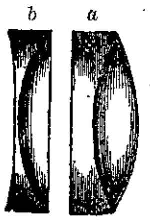


Fig. 7.

MICROSCOPES are of two kinds—Simple and Compound. By the *Simple microscope*, objects are viewed through a single lens, or through two or three lenses placed together, so as to form doublets or triplets. The glass is arranged so that it can be brought over the object, and adjusted, by means of a rack and pinion, or by some other contrivance, to its exact focal distance,—the object, when opaque, being seen by light thrown from above, and when transparent, by light transmitted from below. This instrument, when used with single lenses or doublets, is the best for ordinary botanical investigations, more especially for dissections. The combination of three lenses approaches too near the object to be easily used. A very high power may be obtained by doublets formed of plano-convex glasses, or by means of the lenses termed Coddington's or periscopic, consisting of two hemispherical lenses, cemented together by their plane faces, having a stop between them, or rather having a groove in the whole sphere filled with opaque matter. The chief objections to the simple microscope are the fatigue attendant on long-continued investigations, and the small field of view. In the simple microscope, glasses of the following focal lengths may be employed—viz., $1\frac{1}{2}$ inch, $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$; and, if very minute objects are to be examined, of $\frac{1}{10}$, $\frac{1}{30}$, or $\frac{1}{40}$ of an inch.

When examining minute plants, such as Diatomaceæ and Desmidieæ, during an excursion, it is useful to have a simple microscope similar to that represented in figs. 8 and 9. It consists of a Wollaston's doublet,

Fig. 7. *a*, An achromatic or aplanatic lens, consisting of a double convex lens of plate-glass, and a plano-concave of flint-glass. *b*, Section of the plano-concave lens.

fixed in a round plano-concave brass disc (fig. 8, *a*), attached to a small brass handle (fig. 8, *b*). For ordinary botanical purposes a lens magnifying 65 to 70 diameters is enough; but the lenses may be procured with a power of 150 to 220 diameters. On the plane side of this brass disc, there is a ring of silver (fig. 8, *c*), in which a thin piece of glass is fixed, also supported by a brass handle, which acts as a spring, so as to keep the two rings in contact. In the handle of the first-mentioned disc, there is a screw (fig. 9, *d*), which passes through it, and by the motion of which the

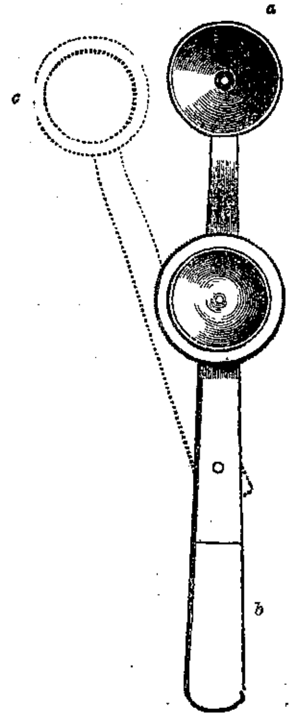


Fig. 8.

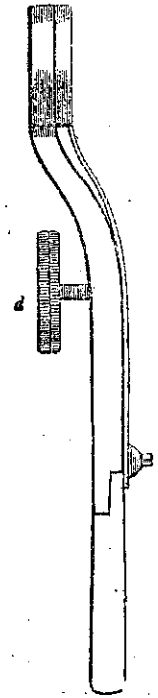


Fig. 9.

two handles can be separated or allowed to come close to each other. By this means an exact focal distance can be obtained. A drop of fluid con-

Figures 8 and 9 represent Gairdner's portable simple microscope.

In fig. 8 there is given a front view of the instrument, showing the posterior silver ring, *c*, enclosing a piece of thin glass, separated and turned aside from the disc, *a*, containing the doublet, to which the eye of the observer is applied. Fig. 9 exhibits a lateral view of the instrument, with the screw, *d*, by means of which the handles are separated or approximated, so as to bring the object into focus.

taining Diatoms, or any minute object, is placed on the outside of the thin glass in the silver ring, and it is then covered by a similar piece of thin glass, which adheres by means of the fluid. The object being brought into focus, as in fig. 9, the observer can distinguish the characters of the microscopic plant, so as to determine whether it is necessary to take specimens home for more careful examination by the compound microscope.

In the *Compound microscope* there are two sets of lenses,—the one called the *object-glass* or objective, the other the *eye-piece* or ocular. The first receives the rays from the object, and bringing them to new foci, forms an image, which the second treats as an original object, and magnifies it just as the single microscope magnified the object itself. The image is inverted, but this may be remedied by making the rays pass through another set of lenses in the tube of the microscope, called the *erector*. In the construction of the object-glasses, great care is taken to render them achromatic. Those made by the most eminent London makers consist of two or three compound lenses, which cannot be used separately, but are fixed together in a tube. In the case of high powers, the object-glasses are also provided with an adjustment for the thickness of the glass covering the object to be viewed. This adjustment makes up for the refraction caused by the passage of light through thin glass of different thickness, and is accomplished by altering the distance between the second and third pair of lenses in the object-glass. This adaptation is especially necessary in the case of a glass with a large angle of aperture. In Ross's microscope, when the mark on the cylinder coincides with the longer mark on the tube of the objective, the adjustment is perfect for an uncovered object; when the coincidence is with the short mark, the proper distance is obtained to balance the aberration produced by glass $\frac{1}{100}$ of an inch thick. The eye-piece, also, must be so formed as to be free from error. That used is called Huyghens', and consists of two plano-convex lenses with their plane sides towards the eye, and placed at a distance apart equal to half the sum of their focal lengths, with a diaphragm inserted midway between the lenses. In this eye-piece, the lens next the eye is called the eye-glass, the other the field-glass. By the Huyghenian or negative eye-piece the object is seen inverted. The Ramsden or positive eye-piece consists of two plano-convex glasses, with the convex surfaces directed towards each other; by it objects are seen erect, and it is often used as a micrometer eye-piece, that is, for measuring objects. The eye-

pieces supplied with the best microscopes are usually three; and they are so constructed, that, with each of the object-glasses, they give a certain amplification of the object, the powers being in the proportion of 1, 2, and 3, or 1, $1\frac{1}{2}$, and $2\frac{1}{2}$. In the best microscopes there is also an *achromatic condenser* or eclairage, through which the light reflected from the mirror passes. The amplification by means of an eye-piece in the compound microscope enables us to use an object-glass of a lower power than would otherwise be necessary. This kind of microscope, when well constructed, gives a flat and colourless picture of the object, with clearness of definition. The observer can use it for a length of time with less fatigue than when employing the simple microscope. Weak eye-pieces and strong object-glasses are to be recommended. The eye-piece does not add either clearness or distinctness to the object, and when it is very powerful the field of view becomes too small to take in the whole image formed by the object-glass; for the magnitude of the field of view and the strength of the illumination diminishes according to the magnifying power of the eye-piece employed. The lower powers are of use in searching for the object to be examined, which may thus be more easily found by a higher power. For the lower power a linear amplification of from 20 to 50 diameters, and for a higher power a linear amplification of from 300 to 500 diameters at most, will give a sufficiently wide range of powers. The powers are increased by a more powerful eye-piece or object-glass, or by both, or by lengthening the tube of the microscope.

In examining vegetable structures, an instrument magnifying 150 to 200 diameters is usually sufficient; but in some instances higher powers are required. Achromatic object-lenses of $1\frac{1}{4}$, $\frac{2}{5}$, and $\frac{1}{4}$ of an inch, are recommended as the most essential; and two eye-pieces should be provided, one of about $1\frac{1}{2}$ and the other of $2\frac{1}{2}$ inches in length. The instrument should have both a coarse and a fine adjustment; and it is of importance that it should be made to incline at an angle, or to stand horizontally. A moveable stage is also useful, so that the different parts of the object may be viewed without being touched by the fingers, and a spring-holder to fix the objects on the stage.

In figure 10 a compound microscope is represented. The stand, or base, consists of a strong tripod, *a*, supporting two upright pillars, *b*, *b*, between the upper parts of which an axis works. This carries the whole of the optical parts of the instrument which can be adjusted to any inclination, horizontal, vertical, or intermediate. The stage, *d*, *e*, is firmly attached to the axis, as is also the double mirror, *f*. The triangular bar, *g*, has a rack on its posterior part, which is worked by a pinion, the milled heads of which are seen at *h*, *h*. The body, *i*, screws firmly into the arm, *j*; the achromatic object-glasses are screwed into the body at *m*; the Huyghenian eye-piece slides into the other end of the body. The mirror is plane on one side, and concave on the other, and is fitted with a universal movement, so as to be inclined in any desired position. The milled heads, *h*, *h*, by being revolved, raise or lower the body, *i*, and constitute the coarse adjustment; the fine adjustment is effected by turning the milled head, *p*. The object to be examined is placed on the stage, *d*, and retained in the required position by the sliding piece, *e*. The quantity of light admitted through the instrument may be modified by the diaphragm, *r*, which consists of a plate of brass with four apertures of different diameters, made to revolve on a central pin or axis fixed to the bottom of the stage. Provision is also made for adding a polarizing apparatus. In addition to the four holes mentioned as needed to admit the requisite amount of light, the diaphragm is furnished with a fifth hole, into which a Nicol's prism may be screwed, forming the polarizer; the analyzer being screwed into the upper part of an adapter previously to its being attached to the body, *i*. The polarizer is mounted on a double tube, so as to be capable of being evolved by turning a large milled head at the bottom. A condensing

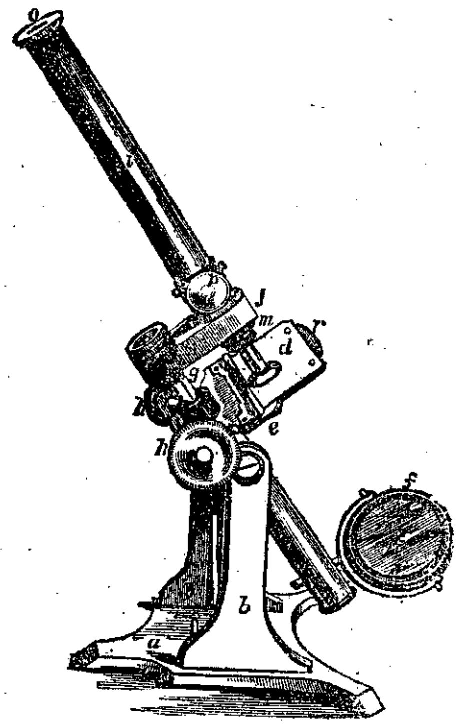


Fig. 10.

Fig. 10. Ordinary compound microscope.

lens for illuminating opaque objects may be fitted into the hole at the corner of the stage; it is so arranged that it can be used in any required position or angle. Among the objects often furnished with the microscope is a plate of selenite, which, if laid under many animal and vegetable structures while being examined by polarized light, will cause them to assume beautiful colours. Nachet has invented a binocular microscope by which the objects are seen in relief.

Very good students' instruments are made by Smith and Beck in London, and by Nachet and Oberhäuser in Paris. One of the latter as used by Dr. Bennett, is shown in fig. 11, which is taken from his lectures on Clinical Medicine. The figure is one-fourth of the real size of the instrument. The body consists of a telescope tube eight inches in length, held by a split tube three inches long. It may be elevated or

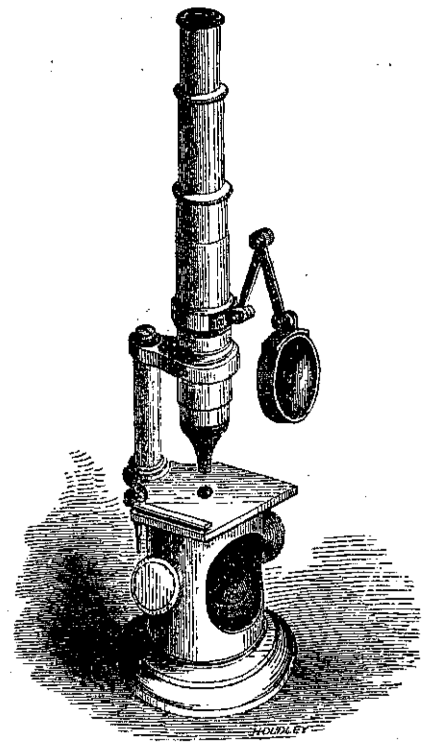


Fig. 11.

Fig. 11. Oberhäuser's portable student's microscope.

depressed by the hand by a cork-screw movement, and this constitutes

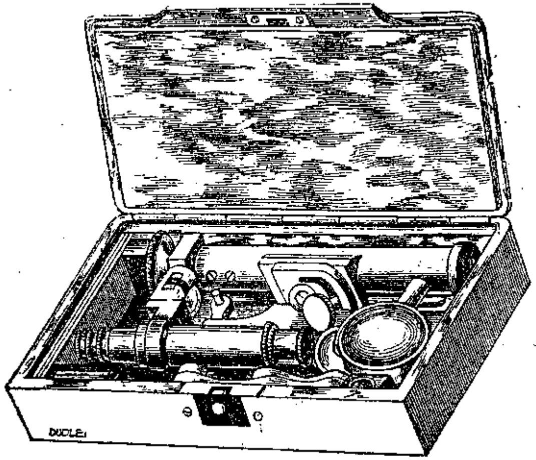


Fig. 12.

the coarse adjustment. It is attached to a cross-bar and pillar, at the

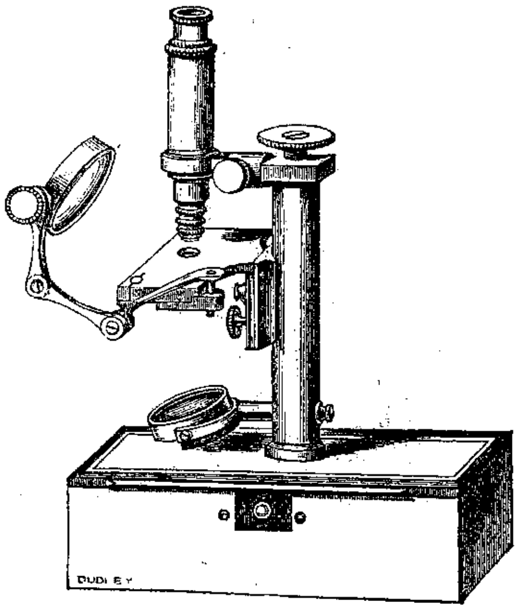


Fig. 13.

Figures 12 and 13 represent Gruby's portable compound microscope one-half its real size.
Fig. 12. The instrument in its case. Fig. 13. The instrument mounted. A full description is given by Dr. Bennett in the Edinburgh Monthly Medical Journal for December 1846.

lower portion of the latter of which there is a fine adjustment screw. The stage is three inches broad, and two and a half inches deep, with a circular diaphragm below it. The base of this portable instrument is loaded with lead so as to give it steadiness. A similar instrument is made by Nachet, in which there is a broader stage, and a broader base, as well as a means of inclining the body of the instrument. It has been preferred by botanical students in Edinburgh, and it is cheaper than Oberhäuser's. The following are the powers (linear measurement) of Nachet's student's compound achromatic microscope:—*

Objectives (Object-Glasses).	Oculars (Eye-Pieces).		
	1	2	3
1	70	90	140
2	190	250	400
5	280	360	600

As a portable compound microscope is sometimes wanted by a student, Dr. Bennett has given the accompanying figures of one recommended by Gruby of Paris. In fig. 12 the instrument is shown in its case, and in 13 it is mounted. The woodcuts are exactly one-half the real size, and give a good idea of the instrument, a detailed description of which is not required. In fig. 14, a representation is given of one of Smith and Beck's microscopes for students. A is the brass stand, supported firmly on three feet, and having two upright flat cheeks, to the top of which the stage-plate, *d*, is fixed. Into the stage-plate is screwed an upright round tube, to which is attached an open tube, *g*, in which the body of the instrument, *f h*, slides. By moving the body up and down in this tube, the coarse adjustment is effected, and when the instrument is brought near to the object on the stage-plate, *d*, a finer adjustment is made by means of the screw with the milled head, *e*, which either raises or depresses the part by which *g* is attached to the upright tube. The mirror is represented at *b*, supported on trunnions, and capable of motion upwards or downwards

* The price of the instrument, with all these powers, is 190 francs, exclusive of duty and carriage; without No. 2 ocular, and No. 5 objective, it is 150 francs.

so as to reflect the light on the object placed on the stage-plate; *c* is the diaphragm, or stop, or perforated plate attached to the stage, with the view of shutting off the extreme rays of light. The object glass or objective is placed at the lower end of the instrument, *f*, and the eye-piece or ocular, at the upper part, *h*.

In fig. 15 a diagram is given to explain the mode in which the compound microscope acts. In this figure, *o* is the object, above which is seen the triple achromatic object-glass or objective, consisting of three achromatic lenses, which are combined in one tube; *e c* is the eye-piece or ocular, consisting of two plano-convex lenses, one at *e*, being the eye-glass, and the other at *c*, the field-glass. Three rays of light are represented as proceeding from the centre of the object, and three from each end of it. These rays have a tendency to proceed so as to form an image of the object at *a*, but coming in contact with the field-glass *c*, they are made to converge and meet at *b*, where the diaphragm is placed to intercept all light except what is necessary for the formation of a perfect image. The image formed at *b* is viewed as an original object by the observer through the eye-glass *e*.

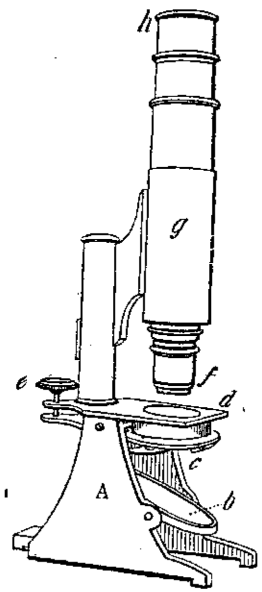


Fig. 14.

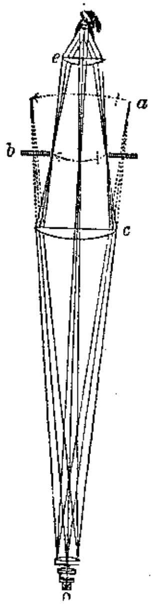


Fig. 15.

MICROMETER.—In measuring the size of microscopic objects, a *micrometer* (μικρὸς, small, and μέτρον, a measure) is employed. The stage micrometer consists of a piece of glass, ruled with fine lines by means of a diamond point, at some known distance apart, such as the $\frac{1}{100}$th or $\frac{1}{1000}$th or $\frac{1}{2500}$th of an inch. A mode of ascertaining the magnifying power of the compound microscope is founded on the assumption, that the naked eye sees most clearly and distinctly at the distance of ten inches. If a divided scale be placed on the stage, and distinctly seen magnified through the instrument, let a rule be held at ten inches' distance from the right eye, while the observer uses, at the same time, his left eye in looking at the other scale through the microscope, and let the rule be gently moved so that it is seen to overlap or lie by the side of the magnified picture of the other scale,—a comparison as to how many of its known divisions correspond with a number of those on the magnified scale, will indicate the magnifying power. Upon a similar principle a pair of compasses may be substituted, whose points being placed on the stage are separated till they cover or mark off so many spaces as magnified by the instrument. If they cover 1 magnified space, and correspond to 2, 3, or more known spaces on the rule, then the instrument is said to magnify 2, 3, or more times linear that known space. If $\frac{1}{100}$th of an inch is found to cover 2 inches on the rule, the instrument magnifies 200 times; if 3 inches, 300 times; if 4 inches, 400 times, and so on. In this way is determined the magnifying power of any combination of lenses, and the scale which is magnified is called the object-glass micrometer. The size of objects may be measured by placing them directly on this micrometer; but it is obvious that they cannot under high powers be brought into focus at the same time as the lines of the micrometer. An instrument called the eye-piece micrometer is therefore generally used. It consists of a known scale ruled on glass, and placed in the focus of the upper glass of the eye-piece. The glass is divided by lines varying from $\frac{1}{25}$th to $\frac{1}{100}$th of an inch apart, and is placed either in the focus of the eye-lens or below the field-lens. It is observed with it how many of its divisions correspond with one division magnified by the microscope. Thus, if with an instrument which is known to magnify 250 diameters linear, it is found that 1 space of the magnified micrometer corresponds with 5 of the eye-piece micrometer, the size of the object will be $\frac{1}{5}$th of the known scale. If the scale be $\frac{1}{1000}$th part of an inch, and the object is seen to correspond to 1, or to 4, or to 5 of those spaces, then its size is the $\frac{1}{1000}$th or $\frac{4}{1000}$th, or $\frac{5}{1000}$th part of an inch. In using the eye-

Fig. 14. Smith and Beck's compound microscope for students. A, brass stand, supported on three feet; *b*, mirror supported on trunnions; *c*, diaphragm; *d*, stage-plate on which the object is placed; *e*, screw with milled head for fine adjustment; *g*, brass tube in which the body of the instrument is moved, so as to effect the coarse adjustment; *f*, the object-glass or objective; *h*, the eye-piece or ocular.

Fig. 15. Diagram to show the mode in which the compound microscope acts. O, an object, with three rays of light from its centre, and three from each of its ends; *e c*, eye-piece, consisting of two plano-convex lenses—one at *e*, the eye-glass, the other at *c*, the field-glass; *b*, diaphragm; *a*, the point where an image would be formed if the rays were not made to converge by the lens *c*.

piece micrometer, the marked side of the glass is put undermost. With this instrument, when using a magnifying power of 500 or 600 diameters, we can estimate distances from $\frac{1}{5000}$th to $\frac{1}{7500}$th of an inch with tolerable precision. Other kinds of micrometers are also employed, such as the cobweb micrometer, where, by the motion of a delicate screw, fine wires or cobwebs are made to separate from each other. Welcker's micrometer has been of late recommended as surpassing the cobweb screw micrometer in elegance of principle and in cheapness. The exact size of objects can only be determined by actual measurement; but at the same time the size may sometimes be conveniently compared with that of any other familiar microscopic object, such as a human blood disc, or the like.

MICROSCOPIC APPARATUS.—In delineating minute structures, it is useful to have the image thrown on paper by means of a *camera-lucida*, or small prism, which can be easily attached to the microscope. In the apparatus sent along with microscopes will be found a *compressorium*, for the purpose of applying pressure to objects whilst they are under examination, troughs for holding such plants as Chara, which are to be seen in water, and various instruments for the dissection and examination both of animal and vegetable structures. In testing the power of an instrument, certain objects are used, in which peculiar markings occur, which can only be properly seen by a fine instrument. Either artificial or natural objects may be chosen as test-objects. The former have been prepared by Robert, a Konigsberg optician, and consist of glass plates, on which are ruled, with a diamond, systems of a hundred lines, which, 10 by 10, approach closer together and are finer, according to a definite standard. With most instruments only the 6th and 7th systems can be distinctly made out to be composed of separate lines. Superior instruments reach the 8th and 9th. No instrument has yet reached the 10th system, with its component lines. The best test-objects are the natural ones, as being regular and uniform in their markings, such as the scales of Podura plumbea or common Spring-tail, of Lepisma saccharina or sugar-louse, of Hipparcha janira or common meadow butterfly, Pontia brassica or cabbage butterfly, the hair of the larva of Dermestes or bacon-beetle, muscular fibrillæ, and the minute markings of the Diatomaceæ, as Pleurosigma hippocampus. Certain markings occur in these *test-objects*, which can only be seen properly by good microscopes.

In viewing objects under the microscope, they must be placed on slips

or slides of glass, which should be of a uniform size, not less than three inches by one; and they should be covered with round or square pieces of very thin glass, $\frac{1}{50}$th to $\frac{1}{100}$th of an inch thick. The slides ought to be made of thin plate-glass, and the covers of very thin crown or plate-glass. In examining recent vegetable structures, it is best to moisten them with water. When the parts are dry, thin sections may be made either by means of slicing instruments, or by a sharp knife. Many dry objects are well seen when immersed in Canada balsam. To preserve objects in a moistened state, the substances used are alcohol, a mixed solution of salt and alum and corrosive sublimate, water containing a small quantity of creasote (5 grains to the ounce), and glycerine. The objects, in such instances, are placed in shallow glass cells, or they are laid on the slides and covered with thin glass, which is cemented by means of japanner's gold size, or black japan varnish. The methods of proceeding are afterwards described.

Polarization and Polarizing Apparatus.—When a ray of light is reflected or refracted in certain peculiar conditions, it acquires remarkable properties, and is said to be polarized.* Light is polarized by reflection, simple refraction, double refraction, and by absorption. Double refraction is seen in certain crystals which have the power of separating a ray of light passing through them into portions. By absorption is indicated the property possessed by certain transparent media of absorbing or stopping a part of a ray of light and transmitting the remainder. In the case of common or unpolarized light it is supposed that the vibration of luminous particles takes place in more planes than one—two of these planes being at right angles to one another, and the particles vibrating first in one plane and then in another. Polarized light, on the other hand, is produced by vibrations in one plane.

Difference between Common and Polarized Light.†

A Ray of Common Light,	*A Ray of Polarized Light,*
1. Is capable of *reflection*, at oblique angles of incidence, in every position of the reflector.	1. Is capable of *reflection*, at oblique angles of incidence, *in certain positions only* of the reflector.
2. Penetrates a plate of *tourmaline*	2. Penetrates a plate of *tourmaline*

* Derived from the supposed analogy to the poles of a magnet.

† Pereira on Polarized Light, p. 48.

(cut parallel to the axis of the crystal) in every position of the plate.	(cut parallel to the axis of the crystal) in certain positions of the plate, but in others is wholly intercepted.
3. Penetrates a *bundle of parallel glass plates*, in every position of the bundle.	3. Penetrates a *bundle of parallel glass plates*, in certain positions of the bundle, but not in others.
4. Suffers *double refraction* by Iceland spar, in every direction, except that of the axis of the crystal.	4. Does not suffer *double refraction* by Iceland spar, in every direction, except that of the axis of the crystal. In certain positions it suffers single refraction only.

A polariscope is used to ascertain whether light has undergone polarization. This consists of two parts, one for polarizing the light, called the polarizer, the other for examining the light, called the analyzer or test. In the compound microscope a prism of Iceland spar (prepared by dividing the oblique rhombic prism into two wedges and then joining the two edges by Canada balsam), is placed under the stage as a polarizer, and a similar prism is placed over the eye-piece as a test. The Canada balsam separates the two images of the doubly refracting spar to such an extent that one only is seen through the prism. Two thin plates of tourmaline may be used instead, and in that case the light is polarized by absorption. When light reflected from the mirror through the polarizer is examined by the analyzer it is found that, upon revolving either the one or the other, the light is twice completely stopped on each revolution, and the field of view darkened. To exhibit the phenomena of polarized light, interpose between the polarizer and analyzer a thin plate of some doubly refracting substance, which is called the depolarizer. This depolarizer divides the ray into two, or produces two systems of waves polarized in planes at right angles to each other. One of these systems traverses the depolarizer more slowly than the other, and thus the two intersect each other, or *interfere*, and in this case colour is usually produced.

A writer in the "North British Review," for 1856, makes the following observations on the polarizing microscope:—Certain structures in minerals and plants, and on the tissues and various parts of animals, are wholly invisible in the microscope. In the cornea and

crystalline lenses of animals in composite minerals, and in simple minerals, such as amethyst, analcime, and apophyllite, in a great variety of crystals, to which the name of circular has been given, and in plants, there are beautiful organisms arising from differences in density, to which the human eye, even if assisted by the best microscopes, is absolutely blind, when viewed by common light. This light as it comes from the sun, and from artificial flame, consists of, or may be divided into, two kinds of light, as electricity may be divided into vitreous and resinous, or magnetism into north polar and south polar. Thus divided, common light is said to be polarized, and the two portions exhibit different properties when reflected from, or transmitted through bodies. If we suppose a cylindrical beam of common light to be composed of different parts, like a number of shillings arranged in a cylindrical row with the queen's heads lying in all directions—then, if one half of the shillings, separated from the other half, have all the queen's heads standing upright, and if the other half have all the queen's heads lying horizontally, we shall have an idea of polarized light. Now, the separation of common from polarized light may be effected by making light pass through several plates of glass, at an angle of about 55°; all the reflected light will be polarized like the cylinder of shillings with the queen's heads upright, and the transmitted light (when the plates are sufficiently numerous) like the cylinder with the heads lying horizontally, Light similarly reflected from a single polished surface of transparent or black bodies, not metallic, will also be polarized. Common light may be divided into two polarized pencils, by passing through certain crystals, such as Iceland spar or quartz. Each pencil is polarized oppositely, and when a rhomb of Iceland spar is cut into two parts, and these parts are combined so that one of the pencils is hindered from reaching the eye, it constitutes a Nicol's prism, now used in the polarizing microscope. In certain crystals, such as tourmaline and herapathite (the sulphate of iodoquinine), one of the pencils is absorbed, and plates of these substances, therefore, are used in microscopes as polarizers. When polarized light has passed through any transparent body, a change is made visible by looking through another polarizer placed transversely to the first polarizer, which is called the analyzer. The structure of the microscopic object is thus displayed in different colours, or in different shades of white light, the colour or the degree of light depending on the thickness of the different parts of the object. The forms thus disclosed to the eye are at once splendid and beautiful.

The polarizing microscope, simple and compound, was first constructed and used by Sir David Brewster in 1815. In the Simple Polarizing Microscope, a single lens or a doublet with a piece of tourmaline the size of the pupil, as the analyzer, is placed between it and the eye; the object is then examined by polarized light produced by reflection or otherwise. The magnifier and analyzer may be united in a lens of tourmaline. In the Compound Polarizing Microscope, the analyzing Nicol's prism is placed immediately between the object glass, and another Nicol's prism, or a small rhomb of spar, presenting one of its pencils to the object, is placed beneath the object. Along with the polarizing apparatus, there is generally sent a plate of selenite (which is a film of sulphate of lime or gypsum) of such a thickness as to polarize a blue of the second order. This plate is used to show weak polarized tints, as well as to show off the colours of polarizing structures by displaying them on a blue ground. When thus exhibited, all the negative tints (as they may be called) are diminished, and all the positive ones are increased; and the effect of the plate is to mark the true character of the phenomenon.

In proceeding to use the microscope, it is necessary to have a variety of tools and apparatus to aid in preparing objects for investigation. These may be arranged beside the observer in such a way that they shall be always within his reach.* A small tray or box, with divisions, containing a pair of needles in handles (such as are used for crotchet needles), a sharp knife or razor, a section-knife (such as that invented by Valentine, and which bears his name), scissors, and a pair of sharp or fine needle-pointed forceps, about three inches long, are among the most essential instruments required. Glass slides may be arranged also upon the same tray for common use, and the thin glasses for covers should be kept in a small box by themselves. In manipulating the object to be examined, certain re-agents are required. These are:—1. Distilled water; 2. Alcohol in the strong state, and also diluted in the proportion of about 1 part to 10 of distilled water. it is the best preserving agent; it removes colour and also air. 3. Ether, which dissolves resins, fats, and oils. 4. A solution of liquor potassæ diluted to about 1 to 20. It *swells* up, and sometimes separates membranes of cells and tubes when they exist in condensed layers. 5. A solution of iodine in Iodde of potassium diluted to the following strength,—namely, 1 grain of iodine to 3 grains of iodide of potassium, and an ounce of distilled water. 6. Chromic acid diluted in the proportion of about 1 to 30 or 40 of distilled water. The last two re-agents chiefly act by colouring the cell walls or the contents of the cells. 7. Sulphuric acid. 8. Oil, such as the finest of that obtained from coal, and known as mineral oil, is to be recommended for examining and preserving objects in. It does not become rancid, nor has it any affinity for oxygen. For the examination of pollen and spores there is nothing better. 9. One part of dry muriate of lime and 3 of water makes also an excellent solution for preserving objects which do not contain starch. 10. Glycerine is the best preserving agent for cells containing starch. 11. Canada balsam; and 12. Turpentine, are most useful re-agents and preservative materials for many dry preparations. 13. Nitric acid; used for separating cells. 14. A solution of hydrochloric acid may also be found useful in removing deposits of carbonate of lime. 15. A solution of acetic acid. 16. A solution of carbonate of potass or soda. These sixteen substances should be arranged in stoppered glass bottles, fitting into a stand or box, so as to be of easy access, and little camel's hair brushes, pipettes, and glass rods, should be arranged beside these bottles, in order to apply the fluid to the object. Lastly, the student should provide himself with a small note-book of good drawing-paper, on which he ought constantly to practise the delineation of the forms or outlines of the objects seen, and he should endeavour to colour them also when required.

Numerous other requisites and appliances will suggest themselves during the course of investigations, and especially such as will secure cleanliness of the object, and of everything used in the research. 1. One who has any regard for his instrument will never suffer it or its lenses to be handled by those unaccustomed to their use. 2. The microscope, when not in use, must be kept under cover, generally under a glass shade. It should never be exposed in a chemical laboratory. 3. Its lenses must be cleansed when necessary by a cloth which is used *only* for that purpose, or by dry elder pith. The cloth best adapted for this purpose is old and frequently washed linen. 4. A separate cloth of a coarser kind is to be used for drying and wiping the slides and covers. 5. Covers of a middle size, from concave disks, such as watch-glasses, up to the size of a wine-glass without the stem, or other bell-shaped jars, are also required to protect the objects, if it is necessary to leave them for any length of time.

* The following details are partly condensed from Schacht's treatise on the microscope, and from the works of Hannover, Quekett, Jabez Hogg, and Beale.

The microscope is used to the best advantage in a room which receives its light from the north, or west, or both. The light which is reflected from a white and motionless cloud opposite to the sun, is the best that can be obtained. If gas-light is to be used, it ought to be corrected or modified by passing it through blue glass shades before reaching the mirror; but for exact observation, daylight is always to be preferred. When observations are made at night, a sperm-oil lamp is used, and the light is transmitted to the mirror through a plano-convex lens, called a condenser. To correct the unpleasant glare attendant on the reflected light from an ordinary mirror, Mr. Handford makes a mirror of thin concave-glass, three inches in diameter, the back rendered white by plaster of Paris. This is mounted on brass, and fitted over the frame of the ordinary silvered mirror, thus not requiring the latter to be removed. The advantage is, that the whole rays reflected from the surface of plaster of Paris are brought into one focus, together with those reflected from the surface of the glass, and thus an equal and brilliant light is produced. In viewing opaque objects, the light is thrown by the condenser directly on the object, and sometimes a metallic speculum, called a *Lieberkuhn*, is connected with the object-glass, by means of which an additional supply of light is obtained. In conducting microscopic observations, great steadiness of the instrument is required, which should accordingly be set upon a very firm and sufficiently large table, so that all the apparatus hitherto mentioned shall be within reach of the observer. It is proper also to begin the examination of objects with the lower magnifying powers, and to pass gradually from them to the use of the higher powers. By such means a far larger portion of the object is seen, and a more correct idea is obtained of the relations of the parts when considered as a whole. Object-glasses, varying from 30 to 50 diameters, are the best to begin with. The eye-glass of lowest power, that is, the longest one of the series, is also the one which ought generally to be used in the first instance, and as long as the power can be increased by object-glasses of greater magnifying power, any more powerful eye-piece should not be used, because by the use of such eye-pieces the image is rendered more obscure, while less light is obtained for its display.

Sources of Errors of Observation. — Extraneous or accidental objects may be present, and may be derived from various sources. Thus, water too long used may bring before the eye both plants and

animals of the lowest forms, which otherwise would not have been present. Fresh water is absolutely necessary, and it may be even recently distilled. Particles of dust, or fibres from the cloths used in cleaning the glasses, may also add to the confusion. These consist, generally, of fibres of paper, linen, woollen, cotton, or silk fabrics, or minute hairs from the brushes used in manipulation. Air-bubbles are almost invariably a source of confusion to the microscopic observer in his first attempts; but once seen and studied, they no longer distract the attention, and the microscopist soon gets into the habit of disregarding their presence. They generally appear in the form of circles of larger or smaller diameter, with a dark black-looking rim, seen by transmitted light; while with incident or reflected light, their rim appears of a white colour. Pressure under a glass cover causes them sometimes to assume very irregular shapes, but possessing the same properties in their margin or outline in their behaviour with the light. It is also necessary to become familiar with the appearances of the lowest forms of animal and vegetable life, such, for instance, as the common forms of infusoria, the yeast, and such like plants; and the different forms of mould. It must not be forgotten also, that the various menstrua used in manipulation contain elements which properly belong to them, and which must therefore be distinguished; for example, the epithelium of the saliva, the blood corpuscles which may be in serum, and crystals which may be deposited in various fluids which are used as reagents. A peculiar motion, known as "molecular motion," is also a phenomenon which must be recognized. It is peculiar to all very small particles or molecules, when they float in a very thin fluid medium. It is best seen in the fine granules of milk when mixed with water, in the milky juices of the plants, and may be observed very distinctly in solutions of India-rubber, or caoutchouc, when dissolved in ammonia. A magnifying power of 400 or 500 diameters is the best for this observation. Another class of deceptions originates in the eye itself. These are the "muscæ volitantes," the nature of which is described as follows by Dr. W. Mackenzie in his Treatise on the Eye.

"The vision of objects on the surface or in the interior of the eye has attracted attention, chiefly in relation to a symptom, to which the name of *muscæ volitantes* has been given. Any spectrum, or visual appearance, which is apt to impose on the mind, and lead one to think that flies are moving before the eye, is called a *musca volitans* (fig. 16).

"The condition comprehends those sensations which arise from, 1. The layer of mucus and tears on the surface of the cornea; 2. Corpuscles between the external surface of the cornea and the focal centre of the eye; 3. Corpuscles between the focal centre of the eye and the sensitive layer of the retina.

"In hanging the head over the microscope, especially if one is affected with catarrh at the time, the globules, by gravitating to the centre of the cornea, not unfrequently appear to the observer so as to impede his view of the object, till by the act of nictitation he clears them away. In telescopic observations, also, the muco-lacrymal spectrum is apt to prove a source of annoyance. Thus, in looking at the sun through a tinted glass, the observer may be unable to distinguish the spots on that body, being perplexed by what seems the reflection of some part of his own eye interposed between it and the sun. This is caused by the layer of mucus and tears on the surface of the cornea.

"If one looks at the flame of a candle two or three feet distant, or at the sky, through a hole made in a blackened card with the point of a fine needle, or through a convergent lens of short focus, such as the eye-glass of a compound microscope, on steadily regarding the luminous field presented to view, four sets of spectra will be seen (fig. 16), independent of the muco-lacrymal spectrum. The most remarkable appears nearest to the eye, and consists of twisted strings of minute pearly globules, hung across the field of view (fig. 16 *a*). The second in point of remarkableness, and the farthest of the four from the eye, consists of watery-like threads, destitute of any globular appearance, and depending chiefly from the upper part of the field (fig. 16 *b*). I call the former the *pearly spectrum*, and the latter the *watery spectrum*. In two distinct planes, between those occupied by these two spectra, float two sets of globules, not aggregated into threads, but insulated. These constitute what I call the *insulo-globular spectra.* The individual globules of the set farther from the eye, being hazy and ill-defined, may be compared in appearance to small grains of sago (fig. 16 *c*). The globules of the set nearer to the eye are clear in the centre, exteriorly to which they present a sharp black ring, and still more exteriorly a lucid circumference (fig. 16 *d*). These four sets of spectra never mingle with one another, so as to change the order in which they stand before the eye; but the pearly spectrum always appears the nearest; then the sharply defined insulo-globular; then the obscurely defined globules; and farthest away the watery threads.

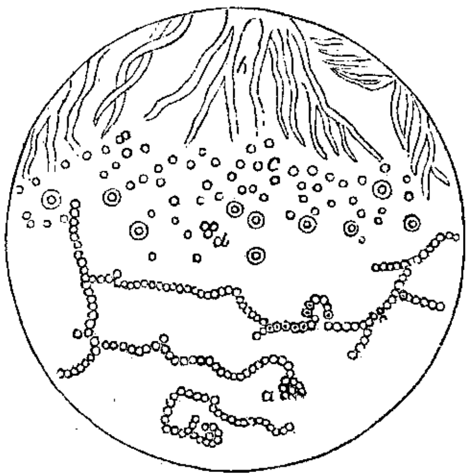


Fig. 16.

Fig. 16. Four sets of spectra, which are apt to cause errors in observations with the microscope.

"Almost every eye, even the most healthy, and which has never attracted the possessor's attention by muscæ volitantes, exhibits the pearly spectrum, on being directed towards a luminous field, through a fine pinhole, the eye-glass of a compound microscope, or a convex or concave lens of short focus. I have given it the same name of the *pearly spectrum*, from its resemblance to a string of pearls. Prevost had already called it *apparence perlée*, or simply *perles*.

"The lines of the pearly spectrum are hung across the field of vision as often transversely as vertically. On first directing the eye towards the luminous field, in one or other of the methods just mentioned, perhaps only a very few small pearly globules are perceived; but after steadily regarding it for a short time, numerous strings of them are discovered, generally twisted in different forms, and presenting a variety of knots, loops, and agglomerations. Sometimes they are so numerous as to form an extensive shower or cloud. The pearly threads are of different lengths; some of them very short, others stretching across the whole field. Not unfrequently some of them end abruptly in a sort of bulb. The globules or pearls forming the threads or rosaries, seemed joined together merely by apposition, without being contained in any tube. Sometimes, however, the globules are rather indistinct, and then the threads approach to a tubular appearance. The globules are always in single rows. They appear destitute of any nucleus. They are not all of one diameter, but are all smaller than the globules of the insulo-globular spectra. I have not satisfied myself that all the pearly threads occupy the same plane, although it is very evident that they are behind the insulo-globular spectra.

"That portion of the pearly spectrum which appears in the centre of the field of view has but little real motion, less perhaps than the watery spectrum which is seen beyond it. Both partake, of course, in the motion of the eyeball; and this gives to both a wide apparent motion. But if the field be examined towards its circumference, or if the eye be suddenly rotated upwards, other pearly spectra appear, which it is difficult or impossible for the observer to bring directly before him; and which, when he succeeds in some measure in doing so, quickly subside again out of view, partly by a real motion of their own, partly by a wide apparent motion, owing to their obliquity in respect to the axis of vision. It is these last spectra, chiefly, which produce the pearly muscæ volitantes."

There are also various optical phenomena caused by refraction, and which are necessary to be attended to. They depend, for the most part, upon a bad adjustment of the focus, or illumination of the object. The appearances are also most frequently associated with an increase of the magnifying power, and especially with the use of powerful eye-glasses. Large grains of potato-starch, pollen-grains, the thickened substance of woody tubes, and the cells of cartilage, are among the most common objects which exhibit such optical phenomena, which consist in a feeble and generally yellowish colouring of the edges of the objects when seen with particular foci.

Focal Adjustment of the Microscope.—The regulation of this adjustment is based on the fact, that the microscope can only afford a view of one surface of an object at any given time, so that nothing is distinctly seen which lies above or below such a focal plane at that time; and the more flat the field of vision, the clearer and better will be the view of objects in that plane if the adjustment is correct. The more perfect the object-glass, and the greater the angle of aperture, * the more exact is this focal plane, and the more sensitive is the instrument to any small alteration of focus. The focal adjustment is made and varied by what is called a fine adjustment screw, and which is sometimes graduated; and the accurate adjustment of the object is judged of by the sharpness of the delineation of the image, as well as by the fineness and clearness of the outline. An experienced microscopic observer always uses the instrument with his finger and thumb grasping the fine adjustment screw, and would not be content with his observation, although it was limited to a mere peep of the object, unless he had made the fine focal adjustment for himself.

* The angle of aperture is that made by two lines from opposite ends of the aperture of the object-glass with the point of focus of the lens. A glass with a large angle of aperture shows objects clearly. The angle varies usually from 50° to 100°. Many glasses, however, are made with a much higher angle. Ross makes glasses of 170° of angular aperture. These are useful for observing minute organisms, such as Diatoms.

Preparation and Selection of Objects for Examination.—Opaque objects require merely to be made smooth or level on one side, and to be fixed on the other. If the object is to be viewed by transmitted light, a section or slice sufficiently thin must be procured; a common sharp knife, a razor, or Valentine's section-knife are the instruments to use. They must be moistened with water, and sometimes it is advisable to make the section under water. If the object is very delicate it may be laid between two pieces of cork, and the whole cut through. Sections should be made in various directions, so that a correct knowledge may be obtained of the relation of the component parts. Maceration in water, and tearing the parts asunder with fine needles, are the best methods for obtaining the ultimate tissues of plants. Thin glass plates to cover the object under the microscope must be invariably used. They prevent evaporation, and preserve the moisture about the object; they prevent the object-glass from being covered with vapour, and so rendered obscure, and, lastly, they produce a slight pressure, by which the elementary parts of the substance may become separated from each other, so as to lie on one plane. The thin covers are not absolutely necessary where very low powers are used. In placing the object on the stage care must be taken not to bring it in contact with the object-glass of the instrument. It is also to be remembered that, in a compound microscope, the image is inverted, and that, consequently, the object is moved in a direction contrary to that of the image.

The following list of tissues to be examined by the student of Vegetable Histology, is taken from the preparations used in the microscopical demonstrations given to the pupils of the Botanical Class in the University of Edinburgh.

Cellular Tissue.—Sea-weeds, Confervæ, Moulds and other Fungi; Lichens, Liverworts, pith of Elder, and of the Rice-paper plants (Aralia and Æschynomene), outer bark as of the Cork and of Elephantipes, succulent roots stems, and fruits, as Orange and Lemon.

Nucleated Cells.—Onion, Yeast plant, Vinegar plant, ripe fruit of Strawberry, Smut, ovules or very young seeds.

Independent Cells.—Red-snow plant (Protococcus nivalis).

Thickened Cells.—Shell of Coco-nut, stone of Peach, Cherry and Nut, seed of Ivory-Palm and Date, gritty matter of Pear, scales of Cone.

Pitted or Porous Cells.—Elder, stem of Common Balsam, outer covering of seeds of Gourd and Almond.

Spiral Cells.—Leaves, stems, and aerial roots of many Orchids, as Oncidium and Pleurothallis ruscifolia, and racemiflora, leaf of Sphagnum, episperm of seeds of Collomia, Acanthodium, Calempelis scaber, Lophospermum, and Cobæa, pericarp of Salvia.

Stellate Cells. — Juncus conglomeratus and other rushes, petiole of Banana and Plantain, and of Sparganium ramosum, stems of many aquatic plants.

Ciliated Cells.—Spores of Vaucheria and some Fuci.

Filamentous Cells.—Fungi.

Pollen Cells.—Anthers of Tulip, Lily, Passion-flower, Acacia (cells united in fours), Zamia, Cycas, Tropæolum, Gloxinia, Colocasia, pollinia of Asclepias and Orchids.

Pollen Tubes.—Œnothera, Antirrhinum, Hibiscus, Linaria, Gesnera, Crocus.

Embryonic Cells.—Orchis, Listera, Hippuris, Euphrasia, Draba.

Spores or Reproductive Cells.—In Cryptogamous plants, Ferns, Mosses, Lichens, Algæ, and Fungi, Zygnema when conjugating.

Cells with Siliceous Covering.—Diatoms, cuticle of grasses, Equisetum.

Cells encrusted with Carbonate of Lime.—Chara.

Epidermal Cells.—Leaves of Hyacinth, petals of Pelargonium, Apple, and Digitalis.

Hairs.—On leaves, and in pappus of Compositæ, Cotton (twisted), articulated hairs on leaves of Goldfussia and Alstroemeria ovata, pappus of Trichinium, moniliform hairs on stamens of Tradescantia, stellate hairs of Deutzia and Aralia papyrifera, peltate hairs of Malpighia urens, glandular hairs of Nettle, Loaza, Chinese Primrose, and Dionæa.

Glandular Cells. — Sweet-Briar, Passiflora lunata, Ice-plant, Lilac, Cinchona, Rhamnus, Rottlera, Aloysia, Mentha.

Scaly Cells.—Ferns, as Polypodium sepultum, and Niphobolus, and Ceterach, Hippophäe, Begonias, Olive, Elæagnus.

Starch in Cells.—Potato, Arrow-root, cereal grains, Bean and Pea.

Raphides.—Hyacinth, Rhubarb, Arum, Onion, Squill, Balsam, Cactus, Lemna trisulca, Ficus, Aloe, Banana, petal of Ornithogalum.

Stomata.—Hyacinth, Begonia, Oleander, Lilium, Equisetum, Box, Gasteria, Marchantia, Crinum, Yucca, Billbergia.

Antheridia and Archegonia.—Prothallus of Ferns, Mosses, Fucus, Marchantia, spermatozoids in Ferns and Chara.

Conjugating Cells. — Zygnema nitidum, Tyndaridea, Cylindrocystis, Desmidieæ.

Vascular Tissue.—Young stems of Herbaceous plants.

Spiral Vessels.—Canna bicolor, Pitcher plant (Nepenthes), Banana and Plantain, Cactus, Hyacinth, Asparagus, Balsam, Strelitzia, branching spirals in Mistleto, Long-leek, and Anagallis.

Annular Vessels.—Opuntia vulgaris, Leek, Equisetum Telmateia.

Dotted Vessels.—Sugar-Cane, Nepenthes, Willow, Clematis Vitalba.

Reticulated Vessels.—Garden Balsam.

Scalariform Vessels.—Common in Ferns, Osmunda, Asplenium, Cheilanthes, Pteris.

Laticiferous Vessels.—Ficus elastica, Euphorbia, Tragopogon, Chelidonium, Lactuca, Isonandra Gutta, Dandelion.

Woody tissue.—Stems of trees, inner bark especially of plants yielding useful fibres, as Lace Bark tree, Cuba Bast, root of Elder, Cabbage.

Punctated Woody Tissue.—Stems of Coniferæ, Pinus, Abies, Araucaria, fossil stems, Cycas, Illicium, and with spirals in Yew.

Preservation of Microscope Objects.—The following apparatus is required, viz., glass-slides ground at the edges, and of the requisite standard size, with circular glass covers. Preserving agents, cement, and a moveable circular disk for mounting and making cells. Among the preserving media for vegetable substances, are—A solution of chloride of calcium, glycerine, copal varnish, mineral oil, Canada balsam. Among the cements used for vegetable objects, are the following:—Brunswick black, japanner's gold size, black japan sealing-wax varnish, Robinson's liquid glue, gum mastic and caoutchouc dissolved in chloroform. Objects are put up (*i. e.*, preserved) either as dry or as wet objects. For dry objects, the oils and the Canada balsam are the preservative materials, and they are not suited for wet objects. Before mounting objects in Canada balsam they should be perfectly clean and free from moisture. They may also be soaked in turpentine, especially opaque objects, as it renders them more transparent. In mounting, the balsam should be heated to expel the air, till a fine delicate film is apparent on its surface. The solution of chloride of calcium is adapted for the preservation of wood and leaves, and for most kinds of isolated tissue. The colouring matter in the cells, however, is always more or less altered by it, while grains of starch, if present, swell up and can scarcely be recognized. The strength of the solution is one part of lime to three of water. Glycerine is used in equal parts mixed with camphor water, which prevents the tendency to mildew. The chlorophyll and the grains of starch remain unchanged, and the laminæ of the starch appear more beautiful after a few hours' immersion in the glycerine solution. Canada balsam and copal varnish are used for the preservation of dry and fossil woods. Thin sections should be made, and the hard woods which contain gum, resin, and such like matters, should be soaked in essential oil, alcohol, or ether, before mounting. If the entire structure of any exogenous wood is required to be examined, the sections must be made both in the transverse or horizontal, and in the longitudinal or vertical directions. The vertical section, made parallel to the medullary rays, or, in other words, along the course of them, shows the nature of these cellular rays, which proceed horizontally from the centre, enclosed between the layers of woody fibres, and which are known to the cabinet-maker as the silver grain of the wood. In coniferous trees, as the pine, this section shows also the beautiful punctations on the walls of the fibres. The tangential-vertical section is a slice across the ends of the medullary rays, and exhibits the form and arrangement of the cellular tissue in them. The cells of the rays are seen projecting between the fibres of the wood. These vertical sections show the form, size, and connections of the woody tubes and the spiral, reticulated, and dotted vessels. In endogenous trees horizontal and vertical sections are also required. Peat wood requires to be digested in a strong solution of carbonate of soda, and fossil woods which have been converted into carbonate of lime should be digested in hydrochloric acid.

Schleiden gives the following method of preserving minute structures for the microscope. Upon a glass slide of the common form, two narrow slips of paper are gummed, of a thickness proportioned to the object, and at a distance which is regulated by its size. Between these the object is laid in a drop of solution of chloride of calcium (one dram to half an ounce

of water). A thin slip of glass, sufficient to cover the object and paper-slips, is put on; the slips are gummed, and the thin glass applied to its place, where it is retained by the gum drying. The whole may be secured by pasting a long slip of paper over all, with a hole for the object. The advantage of this method is preventing *running in.* Chloride of calcium being deliquescent, never dries up, and, if evaporation takes place, water is easily introduced at the open sides of the thin glass. The points to be attended to are—1, that the paper between the glasses be thick enough to prevent much pressure on the object, and not so thick as to allow it to float about or fall out at the side; 2, that the drop of solution be not too large, but covering the object, and yet not reaching the paper. Glycerine may be used in place of chloride of calcium in cases where the objects are very delicate, or contain chlorophyll or albumen.

Small specimens for the microscope, such as Diatoms and Desmidieæ, and many small Sea-weeds, as well as vegetable tissues, are put up in slides 3 inches long by 1 broad (fig. 17), in the centre of which there is a circular cavity formed by a layer of asphalte,* and covered by a circular piece of thin glass. The asphalte is applied by means of a hair pencil, the slide being placed on a moveable brass disc (fig. 18), which has circular marks on it corresponding to the required dimensions of the cavity. The depth of the cavity can be varied according to circumstances, by putting one or more layers of asphalte. After the thin glass cover is put on, it is luted carefully with asphalte. The cavity is filled with distilled water, weak pyroligneous acid, alcohol, diluted glycerine, a very weak solution of creazote (one drop to the ounce of distilled water), or some other fluid. When specimens are very minute, the asphalte-cell is not re-

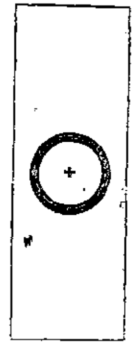


Fig. 17.

Fig. 17. Glass slide for microscopic preparations, 3 inches long and 1 inch broad. In the centre is a ring of asphalte, forming a cell to contain fluid; the object marked by a + in the centre, is covered by a circular piece of thin glass fitted to the asphalte rim. The name of the object is often written on the glass, but perhaps it is preferable to write the name on coloured paper, and attach it to the glass by isinglass or fine bookbinder's glue.

* Prepared asphalte is much better than gold size or black japan varnish, inasmuch as it dries more rapidly, and is less liable to run. It can be procured from Smith and Beck, 6 Coleman Street, London; and from Bryson, 24 Princes Street; Kemp, Infirmary Street; and Hart, North College Street, Edinburgh.

quired; the thin glass is applied at once to the slide, a drop or two of the fluid being inserted along with the specimen. In the case of some dry preparations, as pollen-grains, and the fine-lined Diatoms, no fluid whatever is required, but precautions must be taken against the access of damp.

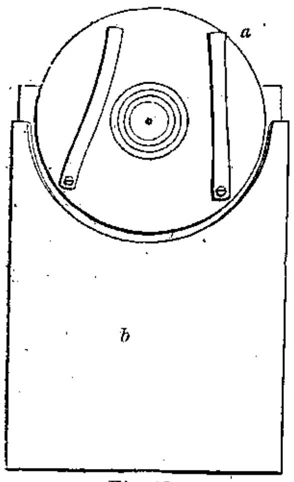


Fig. 18.

Canada balsam is useful in some instances. The specimen is put on a slide, then a minute portion of the balsam is put above it, and the thin glass above all; the slide is heated gently below by means of a spirit lamp until the balsam becomes quite fluid, and until all the air has been expelled by the weight of the glass cover. It is then set aside to dry, and ultimately a rim of asphalte is put round the margin of the glass cover. Canada balsam is well fitted for many Diatoms, and for thin sections of woods. In putting up woods, the specimen is placed in the centre of the glass, a drop of turpentine is put on it to expel the air, Canada balsam is then applied before the turpentine dries, and the same procedure is followed as above.

On preparing fossils for microscopic examination, Mr. Alexander Bryson remarks:*—

The usual mode of proceeding in making a section of fossil wood is simple, though tedious. The first process is to flatten the specimen to be operated on by grinding it on a flat *lap* made of lead charged with emery or corundum powder. It must now be rendered perfectly flat by hand on a plate of metal or glass, using much finer emery than in the first operation of grinding. The next operation is to cement the

Fig. 18. Apparatus for aiding in making the circular rim of asphalte; *b*, a piece of mahogany; *a*, a circular piece of brass, which can be moved round by the hand, and has two brass springs on its surface for holding a glass slide firm. In the centre of the brass disc are circular markings fitted for the size of asphalte cells required. These marks being seen through the slide laid above them, guide the hand in making the circular asphalte rim, the brass disc being turned round during the application.

* On an improved method of preparing siliceous and other fossils for microscopic investigation, with a description of a new pneumatic chuck. By Alex. Bryson, in Edin. N. Phil. Journal, N. S., iii., 297.

object to the glass plate. Both the plate of glass and the fossil to be cemented must be heated to a temperature rather inconvenient for the fingers to bear. By this means moisture and adherent air are driven off, especially from the object to be operated on. Canada balsam is now to be equally spread over both plate and object, and exposed again to heat, until the redundant turpentine in the balsam has been driven off by evaporation. The two surfaces are now to be connected while hot, and a slow circular motion, with pressure, given either to the plate or object, for the purpose of throwing out the superabundant balsam and globules of included air. The object should be below and the glass plate above, as we then can see when all the air is removed, by the pressure and motion indicated. It is proper to mention that too much balsam is more favourable for the expulsion of the air-bubbles than too little. When cold, the Canada balsam will be found hard and adhering, and the specimen fit for slitting. This process has hitherto been performed by using a disc of thin sheet-iron, so much employed by the tinsmith, technically called *sheet-tin*. The tin coating ought to be partially removed by heating the plate, and when hot rubbing off much of the extraneous tin by a piece of cloth. The plate has now to be planished on the polished *stake* of the tinsmith, until quite flat. If the plate is to be used in the lathe, and by the usual method, it ought to be planished so as to possess a slight convexity. This gives a certain amount of rigidity to the edge, which is useful in slitting by the hand; while by the method of mechanical slitting, about to be described, this convexity is inadmissible. The tin plate, when mounted on an appropriate chuck in the lathe, must be turned quite true, with its edge slightly rounded and made perfectly smooth by a fine-cut file. The edge of the disc is now to be charged with diamond powder. This is done by mingling the diamond powder with oil, and placing it on a piece of the hardest agate, and then turning the disc slowly round; and holding the agate with the diamond powder with a moderate pressure against the edge of the disc, it becomes thoroughly charged with a host of diamond points, becoming, as it were, a saw with invisible teeth. In pounding the diamond, some care is necessary, as also a fitting mortar. The mortar should be made of an old steel die, if accessible; if not, a mass of steel, slightly conical, the base of which ought to be 2 inches in diameter, and the upper part $1\frac{1}{2}$ inch. A cylindrical hole is now to be turned out in the centre, of $\frac{3}{4}$ths of an inch diameter, and about 1 inch deep. This, when hardened, is the mortar; for safety it may be annealed to a straw colour. The pestle is merely a cylinder of steel, fitting the hollow mortar but loosely, and having a ledge or edging of an eighth of an inch projecting round it, but sufficiently raised above the upper surface of the mortar, so as not to come in contact while pounding the diamond. The point of the pestle ought only to be hardened and annealed to a straw colour, and should be of course convex, fitting the opposing and equal concavity of the mortar. The purpose of the projecting ledge is to prevent the smaller particles of diamond spurting out when the pestle is struck by the hammer.

Mr. Bryson has contrived an instrument for slitting fossils. The instrument is placed on the table of a common lathe, which is, of course, the source of motion. (Fig. 19.) It consists of a Watt's parallel motion,

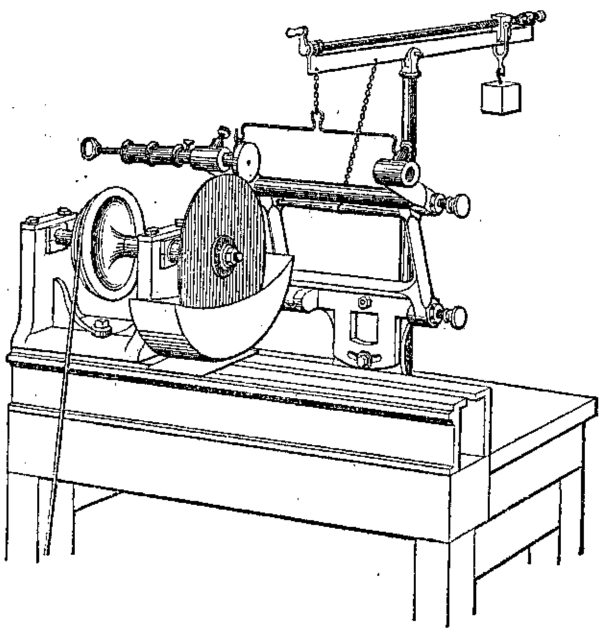


Fig. 19.

with four joints, attached to a basement fixed to the table of the lathe. This base has a motion (for adjustment only) in a horizontal plane, by which we may be enabled to place the upper joint in a parallel plane with the spindle of the lathe. This may be called the azimuthal adjustment. The adjustment, which in an astronomical instrument is called the plane

Fig. 19. Mr. Bryson's instrument for slitting fossils.

of right ascension, is given by a pivot in the top of the base, and clamped by a screw below. This motion in right ascension gives us the power of adjusting the perpendicular planes of motion, so that the object to be slit passes down from the circumference of the slitting-plate to nearly its centre, in a perfectly parallel plane. When this adjustment is made accurately, and the slitting-plate well primed and flat, a very thin and parallel slice is obtained. This jointed frame is counterpoised and supported by a lever, the centre of which is moveable in a pillar standing perpendicularly from the lathe table. Attached to the lever is a screw of three threads, by which the counterpoise weight is adjusted readily to the varying weight of the object to be slit and the necessary pressure required on the edge of the slitting-plate.

The object is fixed to the machine by a pneumatic chuck. It consists of an iron tube, which passes through an aperture on the upper joint of the guiding-frame, into which is screwed a round piece of gun-metal, slightly hollowed in the centre, but flat towards the edge. This gun-metal disc is perforated by a small hole communicating with the interior of the iron tube. This aperture permits the air between the glass plate and the chuck to be exhausted by a small air syringe at the other end. The face of this chuck is covered with a thin film of soft India-rubber not vulcanized, also perforated with a small central aperture. When the chuck is properly adjusted, and the India-rubber carefully stretched over the face of the gun-metal, one or two pulls of the syringe-piston is quite sufficient to maintain a very large object to the action of the slitting-plate. By this method no time is lost; the adhesion is made instantaneously, and as quickly broken by opening a small screw, to admit air between the glass-plate and the chuck, when the object is immediately released. Care must be taken, in stretching the India-rubber over the face of the chuck, to make it very equal in its distribution, and as thin as consistent with strength. When this material is obtained from the shops, it presents a series of slight grooves, and is rather hard for our purpose. It ought, therefore, to be slightly heated, which renders it soft and pliant, and in this state should now be stretched over the chuck, and a piece of soft copper wire tied round it, a slight groove being cut in the periphery of the chuck, to detain the wire in its place. When by use the surface of the India-rubber becomes flat, smooth, and free from the grooves which at first mar its usefulness, a specimen may be slit of many square inches, without resort being had to another exhaustion by the syringe. But when a large, hard, siliceous object has to be slit, it is well for the sake of safety to try the syringe piston, and observe if it returns forcibly to the bottom of the cylinder, which evidences the good condition of the vacuum of the chuck.

After the operation of slitting, the plate must be removed from the spindle of the lathe, and the flat lead *lap* substituted. The pneumatic chuck is now to be reversed, and the specimen placed in contact with the grinder. By giving a slightly tortuous motion to the specimen, that is, using the motion of the various joints, the object is ground perfectly flat when the length of both arms of the joints are perfectly equal. Should the leg of the first joint on the right hand side be the longer, the specimen will be ground hollow; if shorter, it will be ground convex. But if, as before stated, they are of equal length, a perfectly parallel surface will be obtained.

In operating on siliceous objects, I have found soap and water quite as speedy and efficacious as oil, which is generally used; while calcareous fossils must be slit by a solution of common soda in water. This solution of soda, if made too strong, softens the India-rubber on the face of the pneumatic chuck, and renders a new piece necessary; but if care is taken to keep the solution of moderate strength, one piece of India-rubber may last for six months. The thinner and flatter it becomes, the better hold the glass takes, until a puncture occurs in the outer portion, and a new piece is rendered necessary.

The polishing of the section is the last operation. This is performed in various ways, according to the material of which the organism is composed. If siliceous, a *lap* of tin is to be used, about the same size as the grinding *lap*. Having turned the face smooth and flat, a series of very fine notches are to be made all over the surface. This operation is accomplished by holding the edge of an old dinner-knife almost perpendicular to the surface of the *lap* while rotating; this produces a series of *criddles*, or slight asperities, which detain the polishing substance. The polishing substance used on the tin lap is technically called lapidaries' rot-stone, and is applied by slightly moistening the mass, and pressing it firmly against the polisher, care being taken to scrape off the outer surface, which often contains grit. The specimen is then to be pressed with some degree of force against the revolving tin *lap* or polisher, carefully changing the plane of action, by moving the specimen in various directions over the surface.

To polish calcareous objects, another method must be adopted as follows:—

A *lap* or disc of willow wood is to be adapted to the spindle of the lathe, three inches in thickness, and about the diameter of the other laps (10 inches), the axis of the wood being parallel to the spindle of the lathe, that is, the acting surface of the wood is the end of the fibres, or transverse section.

This polisher must be turned quite flat and smoothed by a plane, as the willow, from its softness, is peculiarly difficult to turn. It is also of consequence to remark, that both sides be turned so as that the *lap*, when dry, is quite parallel. This *lap* is most conveniently adapted to the common face chuck of a lathe with a conical screw, so that either surface may be used. This is made evident, when we state that this polisher is always used moist, and, to keep both surfaces parallel, must be entirely plunged in water before using, as both surfaces must be equally moist, otherwise the dry will be concave, and the moist surface convex. The polishing substance used with this *lap* is putty powder (oxide of tin), which ought to be well washed, to free it from grit. The calcareous fossils being finely ground, are speedily polished by this method. To polish softer substances, a piece of cloth may be spread over the wooden *lap*, and finely-levigated chalk used as a polishing medium.

In all instances slides should be labelled with the name, locality, and date, and they should be numbered and catalogued so that they may be easily referred to when put up in cases such as that shown in fig. 20, or in cabinets.*

The Diatomaceæ being either free, or attached to Algæ, etc., different modes must be resorted to for collecting them. Those which are attached require only (either at the time or after being dried) to be rinsed gently in fresh water to get rid of the sand or mud, and salt if any, and then placed in a small saucer in boiling water, with a few drops of nitric or muriatic acid. The cuticle being corroded, the Diatoms fall to the bottom, the floating Algæ are taken out with a glass rod, and the residue washed. This step is merely preparatory to that of burning or boiling the objects. If the Diatoms be free, they should, as far as possible, be gathered free

* In making sections of minute objects, such as Diatoms, they are mixed up with plaster of Paris and mucilage, and then the whole is sliced by means of a sharp razor. Small pieces of wood are sometimes put into a slit in a cork, and then the whole sliced.

from sand or mud, by skimming the surface of the pond or pool with an iron spoon; but as much mud and sand may still be mixed with them, they ought to be afterwards placed in a saucer in a little water, and exposed to

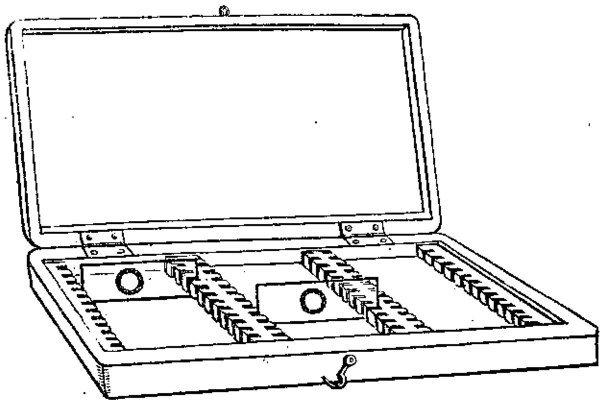


Fig. 20.

the sun for a day or two. A tumbler or hand-glass will prevent too much evaporation. Diatoms, if recently gathered and alive, will come to the surface of the sediment, or water, or both, and this affords an easy mode of separating certain species. They may now be skimmed off with a small spoon, or, what is preferable, a camel's hair pencil, and removed to clean water; and this process is to be repeated till the mud is got rid of entirely. As for preparing the specimens, they may be either burned, or boiled in

Fig. 20. A case for containing slides after being prepared. There are three divisions, each containing twelve slides, two of which are shown projecting above the lower division of the box, the lid being hollowed to receive them. Numbers corresponding to those on the slides are fastened on the partitions at the sides of the grooves which retain the slides. On the front of the box a notice of the numbers contained in it should be fastened. Corresponding numbers, with full particulars as to the preparations, ought to be inserted in a book which serves as a catalogue, in which there should be first a numeral progressive series, and then an alphabetical register for genera. Card boxes for holding 24 slides are made by Smith and Beck and others, price one shilling each. They are excellent for forming a general collection. Cabinets are also made for slides, consisting of drawers half-an-inch deep (including the bottom) divided so as to hold 30, 40, or 50 slides, all on their back; the drawers being slightly bevelled at their divisions on one side, so that the slides may be tilted up by pressing them down. Smith and Beck charge for a cabinet of Honduras mahogany, capable of holding 500 slides, four guineas; 750 slides, five pounds; 1000 slides, six guineas; and 2000 slides, eleven pounds.

nitric acid. For the isolated Diatoms,* as Navicula, Pleurosigma, Cocconeis, etc., boiling is preferable; but for the others, as Synedra, Fragilaria, Melosira, Meridion, etc., if one wishes to have a few frustules cohering together to show their habit, then burning must be adopted, as the acid separates them joint by joint, and valve from valve. This is accomplished by arranging the specimens in the centre of a glass slide, and laying them on a thin iron-slide, and placing the whole within a little iron tray, closed in the form of a slipper, to exclude ashes. This is exposed to the fire till the slide is red hot. The slide is now allowed to cool, and the specimen is ready for being covered either with or without the intervention of balsam. The latter is called *dry* mounting, and is best accomplished by making a ring of asphalte, and following the same process as for liquid mounting, but without liquid. When nitric acid is to be used, the cleaned Diatoms are put into a large-sized test tube of German glass, with as little water as possible, and about one part of nitric acid to four of water. After being boiled for two or three minutes over a spirit-lamp, the Diatoms must be allowed to subside, and as much liquor as possible poured off with any fragments of vegetable matter floating in it. This boiling sometimes suffices, but it is always preferable to add some of the strong acid, and boil the whole again for a few minutes, so as to dissolve any vegetable or animal substances remaining. As the siliceous covering is very thin, and easily broken by a sudden change of temperature, care must be taken in washing away the acid, either to use boiling water, or to allow the Diatoms in the test-tube to cool. When a sufficient supply of *pure distilled* water can be easily got, it alone ought to be used for washing them; but, when that is not the case, ordinary water may be employed for the first washing, but the after washings must be all made with distilled water until the acid is got rid of. After being thoroughly washed, the Diatoms are kept in a small test-tube with some distilled water. In taking the specimens from the test-tube, in order to put them on the slide, a pipette or dropping-tube is employed, having a bore of about $\frac{1}{30}$th to $\frac{1}{50}$th of an inch at its lower end.

Mr. Jackson remarks that it is desirable that no object submitted to higher power than a quarter-inch objective of 75° aperture should ever

* By free Diatoms are meant those that are not parasitical. By isolated or solitary Diatoms are meant those not connected nor cohering together into threads or plates, or by a stipe, tube, or gelatine.

be mounted under a cover thicker than $\frac{1}{140}$th of an inch; if the aperture exceeds 120°, the best thickness for the cover is $\frac{1}{250}$th of an inch.* Glass of this thickness can easily be cut with a good writing diamond, when laid on a piece of plate glass.† To clean the covers, he recommends putting them in strong sulphuric acid for a day or two, and then washing them repeatedly with water; after that placing them, a few at a time, on a tightly stretched clean cambric handkerchief, and rubbing them very gently with another handkerchief on the finger. They should then be removed to a clean box, with forceps, and carefully kept from dust and from contact with the fingers. The covers should be sorted according to their thickness, and this is done at once by Ross's "lever of contact," which consists of a long slender index, having a projecting *touch* near the centre of motion, which is kept in contact with a plane surface by means of a spring. When a piece of glass is inserted under the touch, the index points to the thickness on a graduated arc. The thickness may also be measured in the usual way by placing a fragment in the pliers, with the edge upwards, under the microscope, armed with an inch object-glass and an eye-piece micrometer.‡

To MAKE CELLS, AND TO FIX THE THIN GLASS COVERS.—The cells are made either round or square by thin layers of cement, according to the depth required. Perhaps the round ones are neater, but they require circular pieces of glass for covers, and by the aid of the moveable circular disc, the roundness of the mounting can be made with perfect accuracy. The cover is laid gently down, so as to float on the solution in which the object lies, and by pressing carefully on the cover, the superabundant fluid is made to pass out by the edges, and may be taken up by a sponge or blotting paper. A thin layer of Brunswick black, or liquid glue, or gold size, may be placed round the edge, which will gradually harden and completely seal up the preparation.

* I am informed by a friend, that on account of the brittleness of the glass, covers thinner than 1-140th or 1-150th of an inch are, in the hands of most manipulators, practically useless, as they break by the mere wiping or mounting, and that glass 1-150th of an inch is not too thick either for Smith and Beck's 1-5th object-glass with 100° of aperture, or Ross's 1-8th with 156° of aperture; but that when dry mounting is adopted, the object ought to be arranged on the under side of the cover, thus bringing it as near the lenses as possible.

† Quekett on the Microscope. 2d Edit. p. 265.

‡ Quarterly Journal of Microsc. Science, i. 141.

Directions by Smith and Beck for using the Compound Microscope.

Before using the microscope, see that the mirror, object-glass, and eye-piece are free from dust:—a little soft wash leather should be used in cleaning these. The instrument should be placed on a *steady* table to avoid vibration. The best position for examination by day-light is with the window to the left hand, and the back partly turned toward the window, so that the light may fall directly upon the mirror, and not upon the observer's face. At night, when a lamp is used, a shade should be placed if possible before the lamp, so as to screen the eyes from its glare. The nearer the observer can approach the window by day, and the closer the lamp can be brought towards the mirror at night (say from fifteen to twenty inches) the better; as all the light that can be obtained is required for high magnifying powers; and if too intense for some objects, can be easily modified by the mirror. When the microscope has a joint to the stand, it should generally be used with the body in an *inclined* position—at an angle of about 45°, this being much more convenient for the observer, and not so liable to injure the eye by overstraining it. The management of light, either natural or artificial, is of the greatest importance in microscopic observations. *This may be regulated by altering the position of the mirror under the stage;* the proper adjustment of which will soon be acquired by a little practice and observation. In adjusting the microscope for use, first place it in its proper position, and screw or slide on a low-powered object-glass, then look through the tube, and incline the mirror towards the light, *moving it about until a clear bright light is seen.* The object may then be placed upon the stage and the focus adjusted by the rack movement. In examining any fresh object, the lowest magnifying power should be first used, as a larger portion of it can be thus viewed at once, and a better general idea of its form, colour, etc., obtained. Afterward the higher powers may be employed, in order to reveal its minute structure.

In viewing very delicate transparent objects, as fossil infusoria, thin vegetable and animal tissues, blood and milk globules, etc., a good clear light should be used, but the mirror should be *inclined on one side more than usual, that the object may appear less brightly illuminated.* This is what is termed "oblique illumination,"—the rays of light being reflected from the mirror, through the object, in an *oblique direction*, by which many delicate markings may be observed on some objects which could not be distinguished before, and the outline also rendered more distinct.

In examining *opaque* objects, a low magnifying power should be used, and the light thrown *upon* the object by means of the "Condenser," which should be placed within two inches of it, and so arranged that a small circle of bright light may be seen upon the spot to be examined. When viewing objects in a drop of water, or examining a drop of any other liquid, a slip of thin glass should always be laid over it; otherwise the liquid will evaporate, and condensing on the object-glass, will render it dim.

WORKS ON THE MICROSCOPE.—The following works may be consulted by the student:—Quekett's Practical Treatise on the Use of the Microscope; Carpenter, The Microscope and its Revelations; Schacht, The Microscope and its Application to Vegetable Anatomy and Physiology, translated by Currey; Hannover on the Construction and Use of the Microscope, edited by Professor Goodsir; Beale, The Microscope and its Application to Clinical Medicine; Hogg on the Microscope; Ross, article "Microscope" in the Penny Cyclopædia; Bennett's Lectures on Clinical Medicine, etc.; Transactions of Microscopical Society and Microscopical Journal; Griffith and Henfrey, Micrographical Dictionary; Pritchard's Microscopic Illustrations; Robin, Du Microscope et des Injections.

ROSS' MICROSCOPES IN 1855—OBJECTIVES AND PRICES.

Object Glasses, Focal Length.	Angle of Aperture.	Magnifying Powers, with four Eye-pieces.				Prices.	
		A	B	C	D	£	s.
2 inches	12 degs.	20	30	40	60	2	0
1 inch	15 "	60	80	100	120	3	0
1 "	22 "	60	80	100	120	3	10
$\frac{1}{2}$ "	65 "	100	130	180	220	5	5
$\frac{1}{4}$ "	85 "	220	350	500	620	5	5
$\frac{1}{4}$ "	125 "	220	350	500	620	7	10
$\frac{1}{6}$ "	135 "	320	510	700	910	10	0
$\frac{1}{8}$ "	130 "	400	670	900	1200	11	0
$\frac{1}{8}$ "	150 "	400	670	900	1200	12	0
$\frac{1}{12}$ "	170 "	650	900	1250	2000	18	0

LIST OF THE PRINCIPAL MICROSCOPE MAKERS.—Ross, Powell and Lealand, Smith and Beck, Ladd, Pillischer, Pritchard, Salmon, in London; Adie, Bryson, Hart, in Edinburgh; Field, Parkes, in Birmingham; Dancer, in Manchester; King, in Bristol; Chevalier, Nachet, Oberhäuser, Brunner, in Paris; Schiek, Pistor, in Berlin; Ploesl, in Vienna; Frauenhofer, in Munich; Amici in Modena.

II.—ON COLLECTING AND EXAMINING PLANTS, AND ON THE FORMATION OF A HERBARIUM.

INSTRUMENTS AND APPARATUS.—In examining the characters of plants with a view to classification, the chief instruments required are a lancet-pointed knife, a small pair of forceps and a lens, from $\frac{1}{4}$ to 1 inch focus. With the view of holding the object steadily, the blades of the forceps may be made so as to be fastened by a sliding button. In more minute examinations, the simple or compound microscope must be called into requisition. In selecting specimens, care should be taken to have the plants in a perfect state, or with all the characteristic parts present. The entire plant should be taken when practicable; when that is not the case, then those parts should be taken on which the generic and specific characters are founded. The roots should always be carefully washed at the time the plants are gathered. In most cases, particularly in specimens of Umbelliferæ, Leguminosæ, Compositæ, Rosæ, &c., it is of importance that both flowers and fruit should be preserved. In the case of Willows, the young shoot, with its fully developed leaves, as well as the male and female flowers, are requisite. In Rubi, specimens of the young shoots must be taken. When bulbs or tubers exist, they should be preserved, either in an entire or split condition; and when there is much mucilaginous matter in them, they may be enveloped in small pieces of paper, so as to prevent them from adhering to the drying paper. In the case of Ferns, two fronds are necessary to make a perfect specimen, showing both surfaces, along with a portion of the rhizome. Entire specimens of Gramineæ and Cyperaceæ should be collected; these, when long, may be bent into one or more folds, corresponding to the size of the paper on which they are to be fastened, the folds being temporarily retained by small slips of paper having slits in the centre. No bad specimens ought to be preserved.

In taking up the roots of plants, a small *Digger* or trowel is used, 7 or 8 inches long (fig. 21); the spud $2\frac{1}{2}$ inches long, $2\frac{1}{2}$ inches wide at the top, narrowing gradually to 2 inches at the bottom, the lower angles slightly rounded. It should be sufficiently strong to resist considerable force in digging out plants from the crevices of rocks. The iron portion, which unites the spud to the handle, should be particularly attended to in this respect. This spade is put into a leather sheath, and fastened by a strap round the waist, the spade itself being attached to the strap by a long string. A japanned tin box or *Vasculum* is required for the reception of specimens. This should be of sufficient length to receive a plant of the full size of the herbarium paper; it ought to be convex on both sides

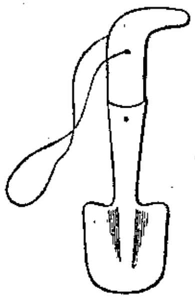


Fig. 21.

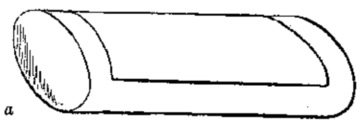


Fig. 22.

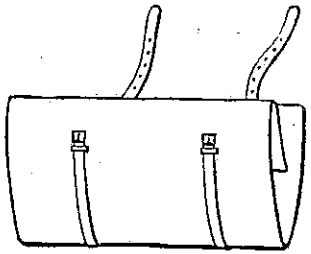


Fig. 23.

(fig. 22); and its capacity may vary according to the wish of the collector. In long excursions where productive localities are visited, it will be found that a vasculum 20 inches long, by 8 or 9 inches wide, and 5 deep, is not too large; and when it is made of thin tin, it is by no means heavy. At one end a good sized thickish handle should be placed, and it is necessary to have wires fixed at each end (*a*) so as to receive a strap for fastening the vasculum on the shoulders. The lid of the vasculum should be large, and is best secured by a wire which slips into a tin sheath, and so constructed as not to be liable to slip out when the box is held by the handle. The specimens should be put into the box in a uniform manner—the flower at one end, and the roots at the other; and care should be taken to have the former (which should be the end where the handle is) always kept on the higher position when carried on the shoulders. For

Fig. 21. Form of spade or digger.
Fig. 22. Form of Vasculum or botanical box.
Fig. 23. Form of Field-book for drying specimens of plants.

mosses and some Alpine species of plants, a small box may also be carried in the pocket. In collecting minute aquatic plants, as Desmideæ and Diatomaceæ, it is necessary to have small glass bottles, or test-tubes fitted to a small case. The corks should be numbered to facilitate notes being taken at the time, of the localities in which the specimens were collected. Many plants will not bear transport; their flowers fall off easily, and they are so delicate that their foliage becomes shrivelled. This is the case with the flower of Trientalis europæa, Rubus Chamæmorus, and Veronica saxatilis, and with some delicate Ferns. In such instances it is best to put them at once into paper. This is managed by having a small *Field-book* (fig. 23), which may be put into the pocket or suspended round the neck, secured by straps so as to give pressure, and with an oil-cloth covering which may be used in wet weather. This field-book may be made with two thin mahogany boards on the outside.

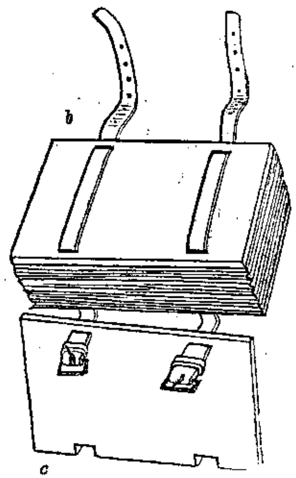


Fig. 24.

A convenient field-book used by students in Edinburgh is represented by fig. 24. It is made of two mahogany boards about nine inches long by five broad, containing from 12 to 24 parcels of paper, each parcel consisting of four sheets, the back of the parcels being covered with strips of leather or cloth. The boards may be rendered firm by being made each of two thin layers of crossed wood fastened together in the way afterwards noticed when speaking of large boards. Two narrow leather straps pass through two holes in one margin of each of the boards, and also through slits in the leather-covered backs of the parcels of the paper, *a*, so as to prevent them from falling out when the field-book is opened. In the case of one of the boards, the two straps also pass through perforations in its other margin, *b*, and under these another strap is passed for the purpose of suspending the field-book round the neck. The two small straps pass through grooves in the margin of the other board, *c*, and are thus buckled so as to apply pressure.

Fig. 24. Small field-book with thin mahogany boards outside, which are brought together by leather straps.

The *Paper for drying* should be moderately absorbent, 18 inches long by 11 broad, and arranged in parcels containing not less than four sheets. The paper which is used extensively in Scotland, is made by Cowan and Co., Princes Street, Edinburgh. In many respects, the Edinburgh botanists prefer it to Bentall's. It is of considerable thickness, absorbs moisture rapidly, but does not become too moist, and dries easily. A very thin kind of paper, called crown tea-paper, is used for holding very delicate plants, which cannot be easily transferred from one paper to another during drying. After being carefully laid out in the folds of this paper, they are placed between the sheets of drying paper, and when the paper is changed they are transferred at once in their thin cover without being disturbed. This plan is useful in the case of such plants as Myriophyllum, Callitriche autumnalis, and other aquatics, as well as Viola lutea, whose petals collapse if removed in the ordinary way, after a day's pressure.

In order that pressure may be given, *Boards* are requisite. These should be exactly the size of the drying paper. Some of them are used for outside boards, and these ought to be from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch thick. Others are inside boards, about $\frac{3}{8}$ of an inch thick. The outside boards are often made double—each double board being composed of two thin ones, the grain of the one crossing that of the other (as in the case of the field-boards already mentioned), closely glued together, and firmly secured by small screws along the edge, at intervals of three inches. They may be rounded on their outer margins. For every two reams of drying paper, not less than ten boards should be procured; two of which are for the outside, and eight for the inside. Sheets of stout pasteboard are also useful for packing up the plants as they become dry. The pressure is best applied on a botanical excursion, by means of a rope put crosswise round the boards and paper, and tightened by a rack-pin. This is much better than straps, which are apt to give way, and are with difficulty replaced during an excursion. In other circumstances, pressure is best applied by means of heavy weights. The pressure ought not to be less than 100 lbs. This is preferable to a screw-press, in which the pressure is not kept up while the plants are losing their moisture. In order to allow free ventilation, and thus to dry plants more rapidly, Mr. Twining recommends, instead of boards, frames made of crossed bars with spaces between them; the surface applied to the paper being flat,—the

others being ribbed by means of prominent cross bars, so as to leave a ventilating space between the one frame and the other (figs. 25 and 26). By an apparatus consisting of eight of such inner frames, and two outer frames of a stouter nature, so as to bear pressure, the plants as well as the paper may be dried rapidly. The apparatus, with paper and plants firmly

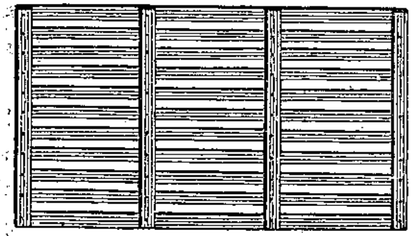


Fig. 25.

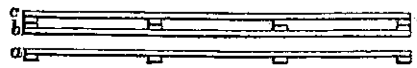


Fig. 26.

strapped, is suspended in a draft of air coming through a partially closed window, or on the branch of a tree in sunshine; and it is said that desiccation of the plants and paper is accomplished in four days. By the use of artificial heat in an open and airy place, as, for instance, by being placed before the fire, the drying may be accomplished in twenty-four or forty-eight hours. Mr. Twining, when in Switzerland, first pressed the plants tightly for twenty-four hours, and then piled them properly in the frame-work apparatus, which was hung up in the hot air of a drying room, and in twenty-four hours more they were ready for packing, the paper also which contained them being perfectly dry and bibulous.* Henslow recommends that, with the view of ventilating plants during drying, holes should be made in the ordinary boards at regular intervals, and that two of the inner boards should always be placed together, separated by flat cross bars which may either be fastened to the boards by liquid glue prepared from shell lac, or may be kept loose, and inserted when required. A complicated apparatus is suggested by M. Gannal, the particulars of which are given in the Botanical Gazette, ii. 55; and there also another mode of drying is described, in which plants, after having been kept in a press for a few hours, are exposed to the sun, or placed on a stove or in an oven, in an apparatus called the Coquette. This consists of two open covers made of strong

Fig. 25. Frames formed of cross bars, for pressure and ventilation.

Fig. 26. Side view of frames. One of the frames *a* seen laterally, with its cross bars forming projections; two of these frames *b* and *c* appear together, so as to allow ventilation between them.

* See a description and drawing of this apparatus, in Botanical Gazette, ii. 59.

iron-wire network fastened into frames made of light iron rod, pressure being applied by straps or ropes, as already mentioned. The open frames allow the moisture to escape freely. Sheets of tin may be employed to separate the different layers of plants in process of drying, so as to hinder the humidity of one from reaching the other, or the inequalities of the larger from injuring the smaller and more delicate. In the case of plants with strong stems, they must either be split, or a sand-bag, of the same size as the boards, used, so as to equalize the pressure.

Process of Drying.—The plants when collected are to be placed on the drying paper. In doing this, a parcel of not less than four sheets is put on one of the outside boards; then the specimens are laid out carefully, preserving as far as possible their natural habits, and laying out the leaves and other parts. Another parcel of drying paper is then placed above these, and the same process is repeated with other specimens until twelve such parcels have been placed together. Then one of the inner boards is laid down, and other layers of paper and specimens are applied, until the whole parcel is of sufficient size to be subjected to pressure. After twelve hours' pressure, in most instances, the paper is changed, the moist paper being hung up to dry; and in transferring the specimens from the wet to the dry paper, a large pair of surgeon's forceps is used. The interval elapsing between the changing of the paper may be increased or diminished according to the nature of the plants, and the state of the weather. In the course of eight or ten days, ordinary specimens will be so dry as to require only very slight pressure, with a moderate circulation of air. Some very dry plants, as grasses, may require only one changing. Succulent plants, such as Sedum and Sempervivum, continue to grow, however much submitted to pressure and the ordinary methods of desiccation already indicated. In order to dry these plants completely and rapidly, it is necessary to kill them, by immersion in boiling water for five or ten minutes. The plants thus dealt with are then placed upon a cloth and left to drain for some time, after which they must be carefully placed between the folds of the drying paper, not forgetting to lay out properly any of the parts which the water may have disarranged. Orchideous plants are sometimes put into warm paper, and changed frequently, with the view, if possible, of preserving their colours by the rapidity of drying. Scarification has sometimes been adopted with the view of allowing the juice to flow out rapidly. Motley recommends that Orchids should be put into weak

spirit for one or two nights, and then dried. In the case of some thick-headed plants, as Thistles, the capitula must either be cut, or they must be crushed between paper by temporary pressure from the foot; this treatment must also be applied to such plants as Eryngium maritimum and the Holly. Sometimes the flower or parts of the flower may be separated advantageously during drying by the insertion of small pieces of blotting paper. At the time the specimens are laid out on the drying paper, a label should be inserted with the date of collecting, the name of the station, its elevation above the sea (if it can be ascertained), and any remarks as to soil or geological structure that may be known. In the course of long excursions, it is necessary to devote every now and then some time to the proper arranging and tallying of the specimens. On this subject, Greville says, "half a day, therefore, at least, in the middle of the week, say the morning of every Wednesday till two o'clock, should be appropriated to the preservation and arrangement of your plants; and a part or the whole of every Saturday should invariably be set apart for the same purpose, in order that they may not be injured by remaining untouched on the Lord's Day." With the view of transporting dried plants securely in wet weather, it is useful to have a supply of oil cloth to cover them.

Mosses may be collected in excursions in tufts, and dried by moderate pressure at first. They can afterwards be separated, moistened, and dried with greater pressure. They ought to be gathered in fructification. In preserving minute Mosses, Dr. C. Müller takes clear talc, splits it into thin layers, and cuts it into oblong pieces of proper size. Then, with a penknife, he splits one of these pieces (from one of the narrow sides) *half-way through*, so that it may be opened to admit the object and then close by its elasticity, the unsplit end serving as a holder. A drop of water is introduced into the slit with the object. When laid aside it dries, and may be rendered fit for microscopic examination by dipping in water. Lichens sometimes require to be taken with the rocks or stones to which they are attached, and they may be merely wrapped up in paper. Sea-weeds must be washed with fresh water before being laid out. The more delicate kinds are floated out on pieces of stiff paper, and afterwards dried by moderate pressure. In preserving fungi, such as Agarics, etc., a thin slice is taken from the centre, extending from the top of the pileus to the base of the stipe. This is dried separately to show the gills or pores, etc. The inner cellular portion of the pileus and stipe is then removed and these parts are dried so as to give the form. Travellers visiting foreign countries (although not botanists) will find it an easy matter to preserve Mosses, Lichens, and Sea-weeds in a state fit for after-examination. In the case of Sea-weeds, it is necessary to avoid such specimens as are in a state of decay. Those which are taken should be spread out in the shade to dry, without washing them with fresh water, and when quite dry, packed loosely in a box. Many species are found thrown upon the beach, and the pools in the rocks at low water are often filled with excellent specimens. The stems of the larger Algæ are often covered with parasitic species, which should be dried without separation.

When the specimens (whether Phanerogamous or Cryptogamous) are fully dried, they are then selected for the herbarium, and are fastened upon fine stiff paper, fit for writing upon, 17 inches by $10\frac{1}{2}$.* In large herbaria, which are constantly consulted, the best way of securing the specimens is by means of fine thin glue; the plants, after the glue is put on them, being made to adhere to the paper, by pressure between folds of drying paper. Some use gummed paper, others use thread or narrow ribbon, by means of which the specimens are sewed to the paper. Plants of certain families, as Compositæ, are more particularly exposed to the ravages of insects. Hence, all plants after being dried, should be brushed over with an alcoholic solution of corrosive sublimate.† This treatment has the inconvenience of discolouring them more or less completely, and making them assume a light brown tint; but there can be no hesitation between the alteration of their colour and the complete destruction with which they are menaced, if not submitted to the above manipulation; some recommend cyanide of potassium to destroy insects. In herbarium-presses camphor is employed to prevent the attack of insects. The specimens must be kept dry, and frequently examined, and when insects are present, they must be retouched with the solution already indicated. Dry fruits, specimens of wood and bark, large roots, lichens and minute Algæ in rocks or stones, or other specimens which cannot be preserved in a herbarium, may be either placed in drawers, in glazed cases, or in glass jars.

The size of the wooden Case for the herbarium must of course depend

* The paper used in Edinburgh is made by Cowan and Co. under the name of "M. B. Laid Medium, flat 4to," and costs two guineas a ream when cut.

† The solution commonly used consists of 30 grains of camphor, and 20 grains of common sublimate to an ounce of alcohol.

on the extent of the collection. In a private collection it is better to have numerous small Cases which are easily removed at pleasure along with the specimens. This should be particularly attended to by medical students and others who have the prospect of going abroad, and who may wish to transport their collections to foreign countries. In such instances, the Cases should be strongly made, and should be not more than four feet high, with two rows of drawers. These drawers are made open in front, and should slide freely in the Case. In the Edinburgh University Herbarium, the size of the drawers or trays is—depth (inside measurement) 4 inches, length 19 inches, and breadth $11\frac{1}{2}$ inches. The size of the trays should of course correspond to that of the herbarium paper. Some collectors have peculiar fancies in regard to the size of their herbarium. Thus a valuable collection of Cryptogamic plants and grasses left by Menzies to the Edinburgh Botanic Garden has the following dimensions:—Height of the mahogany cases 30 inches, breadth in front $28\frac{1}{2}$, from front to back 11; depth of the trays (inside measurement) $4\frac{1}{2}$ inches, length $9\frac{1}{2}$, breadth 6.

Specimens in a Moist State.—In preserving fresh specimens of fruits, and the other parts of plants, the best mode is to put them into a saturated solution of salt and water. They can thus be sent home from foreign countries in jars or barrels. In making a museum of such specimens, they are put into glass jars, the sizes of which should be regular—4, 8, 12, and 16 inches high, with a diameter varying according to the size of the specimen. The glasses may be filled with the following solution, which is nearly the same as that used by Goadby, and which seems to answer well in most instances:—

Bay salt	4 ounces.
Burnt alum	2 ounces.
Corrosive sublimate	5-10 grains.
Boiling water	2 quarts.

Dissolve and filter the solution. Alcohol is often used, but it usually makes all colours alike brown. It is useful for delicate specimens which are required for dissection. Pyroligneous acetic acid diluted with from 3 to 5 parts of water is also very generally employed. Specimens, however, in the acid are apt to become pulpy and brittle after a few years, so as not to admit of being handled; most colours are altered by it. Before being put in jars, fresh specimens should be kept for a month or more in the solution, so as to allow any colouring matter and other impurities to be separated, otherwise the preparation will become obscure and require to be re-adjusted. The mouth of the glass jars may be conveniently covered with India rubber, or in the case of glasses of small diameter, with a watch glass secured by sealing wax, or by circular glass covers cemented by a lute composed of resin 1 part, wax 2 parts, and vermilion 1 part. The glass cover on the top of the jar may be either luted or held in its place by a metallic ring (fig. 27*a*), which is fitted carefully to it, and covers a portion of the glass lid. Two grooves may be made on the inner side of the rim at the top of the jar for holding a piece of whalebone, to which the specimen may be attached by means of a thread, as seen in the figure. In the case of dry preparations, the metallic ring answers well.

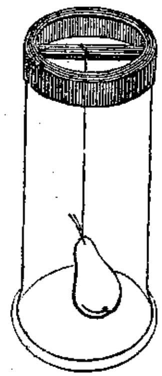


Fig. 27.

It is difficult to keep the solution of salt in the preparation jar. Dr. Christison says:—"The most effectual method, when the mouth of the jar does not exceed 2 or 2½ inches in diameter, is to have a space half an inch or more at the top of the fluid, to clean and dry the top of the jar thoroughly, to drop melted sealing-wax on the upper surface of the top, so as to form a uniform ring over it, to place over the mouth a watch-glass of such size as to cover the whole lip, and even to overhang it a little, to press this gently down with one finger, and to fuse the wax between the top of the jar and the watch glass, by moving a large spirit flame around the edge." Where the mouth of the jar is large, then a round flat piece of glass may be used, or sheet caoutchouc. The latter, after being gently heated, is stretched moderately, not strongly, by one, or still better, by two persons, while a third secures round the neck two or three folds of stout twine as a temporary ligature. A stout thin cord is then drawn steadily and tightly round three or four times above the former, taking care that the caoutchouc is not cut, and that the turns of the twine lie regularly above each other; and finally, that a secure knot is made.

SEEDS, when sent from abroad, should be collected perfectly ripe and dry, and if possible kept in their entire seed-vessels. Small seeds may be folded in cartridge paper, and should be kept in a cool and airy place

Fig. 27. Jar for holding wet or dry preparations, the glass cover at the top being held in its place by a metallic ring.

during transport. Large seeds and oily seeds, which lose their germinating power speedily, are best transported in earth. A box about 10 inches square, with the sides ¾ of an inch thick, answers well. In this may be put alternate layers of earth and seeds, the whole being pressed firmly together. Living plants are best transported in Wardian cases, and seeds or fruits may also be scattered in the earth of the cases. Bulbs and rhizomes not in a state of vegetation, cuttings of succulent plants, as aloes and cactuses, and the pseudo-bulbs of Orchideous plants, may be put into a box or barrel with dry moss, sand, peat, or sawdust.

Hints as to the preparations to be made for alpine travelling, particularly in Switzerland, partly taken from Wills' "Wanderings on the High Alps."

A botanical trip for six weeks in Switzerland, including the expense of going and coming, need not cost more than twelve shillings a day. In a pedestrian tour the traveller must be as lightly equipped as possible; at the same time he must so provide as to have a change of dress in case of wet weather. The Botanist must send his heavy portmanteau and his drying paper, with boards, rope, and rack-pin, to different points by railway or post. During his alpine rambles, he will find that he can only carry his box, spade, field-book, alpenstock, and light waterproof. His knapsack, *while he is botanizing*, must be carried by a porter. He should, however, be prepared on an emergency to carry all his alpine baggage with him, more especially when passing from one station to another by some beaten track, where few plants are to be expected. A large party will find it convenient and economical to hire a horse for the conveyance of their knapsacks.

The articles required are as follows:—

A light waterproof knapsack, which will bear rough usage, about 14 inches long, 10 inches broad, and 3½ inches deep, with two light straps at the top to hold a very light waterproof, and a stout leather handle by which to carry it, if necessary. The straps for the shoulders should be broad. One of the shoulder straps should end in a ring, and a hook should be fastened on the lower edge of the knapsack to receive it. By this contrivance the knapsack is easily taken off. The whole apparatus ought not to weigh above 2 lbs.

Good shoes, large, so as to allow for the swelling of the feet, the soles from $\frac{5}{8}$ to $\frac{3}{4}$ of an inch thick, studded with stout nails, not too thickly. They should be worn with gaiters, so as to keep out dust, stones, etc.

Soft woollen socks, such as those made in Shetland. Of these two or three pairs are required.

A shooting coat, a waistcoat, and trousers of flannel, or of shepherd's plaid, the two former being double-breasted. Flannel should always be worn next the skin on account of rapid changes of temperature on the glaciers and in the valleys.

A light wide-awake hat with strings or elastic band. In very hot weather the action of the sun on the forehead and temples may be diminished by a thick roll of white muslin round the hat.

A light waterproof of silk; one may be got weighing only six ounces.

The contents of the knapsack should not weigh more than 6 or 7 lbs. They should consist of two spare thin merino shirts, three or four pairs of socks, well run in heels and toes, a very thin pair of trousers or drawers for change, two pocket handkerchiefs, and a pair of light shoes; materials for mending—as needles, thread, worsted, tape, buttons, bits of cloth and flannel; also string, soap, sponge, brush and comb, razor, and tooth-brush; oiled-silk, lint, and bandages; ordinary medicine—as compound rhubarb pills, opium, and sugar of lead and opium pills, tartar emetic, lard, and sticking-plaster; a small quantity of note-paper, ink, pens, wafers; a large knife, furnished with a corkscrew, gimlet, and saw; lucifers; a pair of dark spectacles, and a dark veil, and warm gloves and muffitees. There may be also added a journal, a thermometer, compass, clinometer, whistle, and a small telescope. A flask and drinking-cup will also be of service, and a common coarse blouse, which can be procured in Switzerland for two francs. For travelling on glaciers a few screws, about $\frac{3}{8}$ of an inch long, with large double-pointed heads, are useful. Wills procured them at Chamouni. These are screwed into the sole, three or four being enough for each shoe.

For glacier work, stout ropes, thicker than a window-sash cord are required, 10 to 15 feet for each person, and an ice hatchet. An alpenstock, 6 feet in length, is of essential service. A good map is also of great value. The botanist must also have a small tin box, 10 or 12 inches in length, and about 4 deep; a small spade, in a leathern case, fastened round his waist, and a small field-book for drying plants, made of thin wooden boards, 8 or 9 inches long, and about 5 inches broad, and containing drying paper, about

1 or $1\frac{1}{2}$ inch deep. The plants gathered must be transferred to larger drying paper at different stations, and must then either be carried by a porter, or sent by conveyance of some sort.

It is by no means necessary to have guides in every part of the Alps of Switzerland. For instance, Mr. Wills says, that none are required for the Col de Balme, the Tête Noire, the Col de Vose, the Great St. Bernard, the Gemmi, and the Grimsel. In wandering, however, among the high mountains, it is always safe to take a guide. Wills suggests that the best way is to secure a good guide at starting, and keep him during the whole tour. He costs about five or six francs a day.

Directions to Collectors visiting Foreign Countries, condensed from Hooker's Kew Miscellany, Vol. IX., p. 214–219.

A Botanist visiting a foreign country should make as perfect a collection as possible of all the plants, neglecting no species and preserving specimens of every kind, more especially such as seem to be confined to certain localities. The arborescent plants, trees of every description, are to be sought for and collected in flower and in fruit; cones and larger acorns, and other kinds too large for the hortus siccus, are to be preserved apart from the foliage, and notes made of the locality, height, bulk of the trunk, etc. In proportion as mountains are ascended, the vegetation will be found to change and to become more interesting and more peculiar. Particular notice should be taken of the heights at which different plants grow, and of those plants which are found nearest to the limit of perpetual snow. Care should be taken to preserve the collections from wet and damp. They may require to be opened occasionally, and exposed to a dry air or artificial heat. Seeds should be collected, and transported in the way already noticed. Objects of interest as regards economic botany should be collected; such as articles of food, clothing, ornament, medicines, resins, dye-stuffs, samples of woods, particularly those good for carpentry and cabinet-work. Varieties and abnormal forms of species should be sought for and preserved; attention being paid to differences in habit and in the form of leaves and flowers in the same species at different periods of growth and in different conditions of growth. A comparison should be instituted between the flowers of different regions, as of the plains, swamps, and of different heights and exposures on the mountains, as well of different geological districts, as granite, limestone, etc. The times of leafing and flowering of bushes and trees, etc., should be noticed. When the vegetation seems unusually retarded or accelerated, the temperature of the surface soil and at three feet deep should be ascertained, wherever possible. The collector should, as soon as possible, make himself acquainted with the names of the more common and conspicuous plants of the district he traverses, by consulting any works which may have been written regarding it. The plants which affect waysides or the tracks of man and animals should be noticed, and the effect of clearing away forests and of burning grass land on the subsequent vegetation should be attended to. The transport of seeds by man and animals is a subject of great interest, which should not be neglected. Care should be taken to ticket the specimens, so that there may be no difficulty in determining their localities afterwards. Notes as to elevation (if above 2000 feet of the sea level), dates, name of district, and any other information, should be attached to the specimens to which they refer. A collector cannot be too careful in regard to these matters. Ascertaining the temperature of the trunks of evergreen and deciduous trees and of the soil at their roots is a subject of importance. The temperature of the soil at various depths during winter should be recorded; also the temperature of the air and water between the under surface of melting snow-beds and the subjacent dormant vegetation, with the view of determining the causes of the rapidity with which plants germinate and blossom after th disappearance of snow from alpine situations.*

* For fuller details see instructions by Sir Wm. Hooker and Dr. Hooker in Kew Miscellany Vol. ix., pp. 214-219.

GLOSSARY,

OR

EXPLANATION OF SOME OF THE MOST IMPORTANT BOTANICAL TERMS.

A, *alpha*, privative of the Greek, placed before a Greek or Latin word, indicates the absence of the organ; thus, *aphyllus*, leafless, *acaulis*, stemless.
ABAXIAL or ABAXILE, not in the axis, applied to the embryo when out of the axis of the seed.
ABNORMAL, deviating from regularity or from the usual form or structure.
ABORTION, suppression of an organ, depending on non-development.
ABRUPT, ending in an abrupt manner, as the truncated leaf of the Tulip tree; *abruptly-pinnate*, ending in 2 pinnæ, in other words, paripinnate; *abruptly-acuminate*, a leaf with a broad extremity from which a point arises.
ABSCISSION, cutting off, applied to the separation of the segments or frustules of Diatoms.
ACAULIS or ACAULESCENT, without an evident stem.
ACCRESCENT, when parts continue to grow and increase after flowering, as the calyx of Physalis, and the styles of Anemone Pulsatilla.
ACCRETE, grown together.
ACCUMBENT, applied to the embryo of Cruciferæ, when the cotyledons have their edges applied to the folded radicle.
ACEROSE, narrow and slender, with a sharp point.
ACHENE or ACHÆNIUM, a monospermal seed-vessel which does not open, but the pericarp of which is separable from the seed.
ACHLAMYDEOUS, having no floral envelope.
ACHROMATIC, applied to lenses which prevent chromatic aberration, *i. e.*, show objects without any prismatic colours.
ACICULAR, like a needle in form.
ACICULUS, a strong bristle.
ACINACIFORM, shaped like a sabre or scimitar.
ACINUS, one of the pulpy drupels forming the fruit of the Raspberry or Bramble.
ACTINENCHYMA, cellular tissue, having a star-like or stellate form.
ACOTYLEDONOUS, having no cotyledons.
ACROCARPI, Mosses having their fructification terminating the axis.
ACROGEN and ACROGENOUS, a stem formed by the bases of fronds in ferns, increasing by its summit, and having its vascular tissue in the form of irregularly formed bundles.
ACULEUS, a prickle, a process of the bark, not of the wood, as in the Rose; *Aculeate*, furnished with prickles.
ACUMINATE, drawn out into a long point.
ACUTE, terminating gradually in a sharp point.
ADELPHOUS or ADELPHIA, in composition, means union of filaments.
ADHERENT, united, adhesion of parts that are normally separate, as when the calyx is united to the ovary.
ADNATE, when an organ is united to another throughout its whole length, as the stipules in Rose, and the filament and anther in Ranunculus.
ADPRESSED or APPRESSED, closely applied to a surface, as some hairs.
ADUNCUS, crooked or hooked.
ADVENTITIOUS, organs produced in abnormal positions, as roots arising from aërial stems.
ÆSTIVATION, the arrangement of the parts of the flower in the flower-bud.
AFFINITY, relation in all essential organs.
AGAMOUS, the same as *Cryptogamous*.
ALA, a wing, applied to the lateral petals of a papilionaceous flower, and to membranous appendages of the fruit, as in the Elm, or of the seed, as in pines.
ALBUMEN, the nutritious matter stored up with the embryo, called also *Perisperm* and *Endosperm*.
ALBURNUM, the outer young wood of a Dicotyledonous stem.
ALGOLOGY, the study of Sea-weeds.
ALSINACEOUS, a polypetalous corolla, in which there are intervals between the petals, as in Chickweed.
ALTERNATE, arranged at different heights on the