JOURNAL

OF THE

ROYAL MICROSCOPICAL SOCIETY;

CONTAINING ITS TRANSACTIONS AND PROCEEDINGS,

AND A SUMMARY OF CURRENT RESEARCHES RELATING TO

ZOOLOGY AND BOTANY

(principally Invertebrata and Cryptogamia),

MICROSCOPY, &c.

Edited by

FRANK CRISP, LL.B., B.A.,

One of the Secretaries of the Society
and a Vice-President and Treasurer of the Linnean Society of London;

WITH THE ASSISTANCE OF THE PUBLICATION COMMITTEE AND

A. W. BENNETT, M.A., B.Sc., *Lecturer on Botany at St. Thomas's Hospital,*

F. JEFFREY BELL, M.A., *Professor of Comparative Anatomy in King's College,*

S. O. RIDLEY, M.A., *of the British Museum,* AND JOHN MAYALL, JUN.,

FELLOWS OF THE SOCIETY.

Ser. II.—VOL. I. PART 1.

PUBLISHED FOR THE SOCIETY BY

WILLIAMS & NORGATE,

LONDON AND EDINBURGH.

1881.

MICROSCOPY, &c.

a. Instruments and Accessories.

Bausch and Lomb Optical Company's "Professional" and "Investigator" Microscopes.—(1) *Professional.* The description of this instrument was received too late to be inserted in its proper place in order of date, under the head of "Swinging Substages." * It appears to have been made in 1876 (Fig. 4, one-third actual size). It is provided with a heavy brass foot, inlaid with three soft rubber pads under the claws. Two solid brass pillars support the trunnion axis on which the limb inclines, and milled screws are on the ends of this axis for tightening the motion. The coarse adjustment is by rack and pinion moving a long prismatic slide attached to the body, and arranged to compensate for wear.

The substage for receiving accessories of English standard size has two revolving diaphragms, one of the latter belonging to the condenser, all attached to the swinging mirror-bar, the axis of which is fixed in the plane of the object, so that the diaphragm and mirror swing concentrically around it. The mirror as well as the substage can be moved on the mirror bar to and from the object, and both can be removed, the latter by a prismatic slide.

Since the figure was made, a modification of the stage-fitting permits the swinging mirror-bar and substage to be swung above the stage for the illumination of opaque objects. An auxiliary ring, with internal " Society " screw is supplied for use in the substage, so that objectives may be used as condensers.

An immersion condenser, mounted in brass, fits either in the stage or substage. It consists of a truncated cone of crown glass, with a convex base, designed to focus the illumination upon the object.

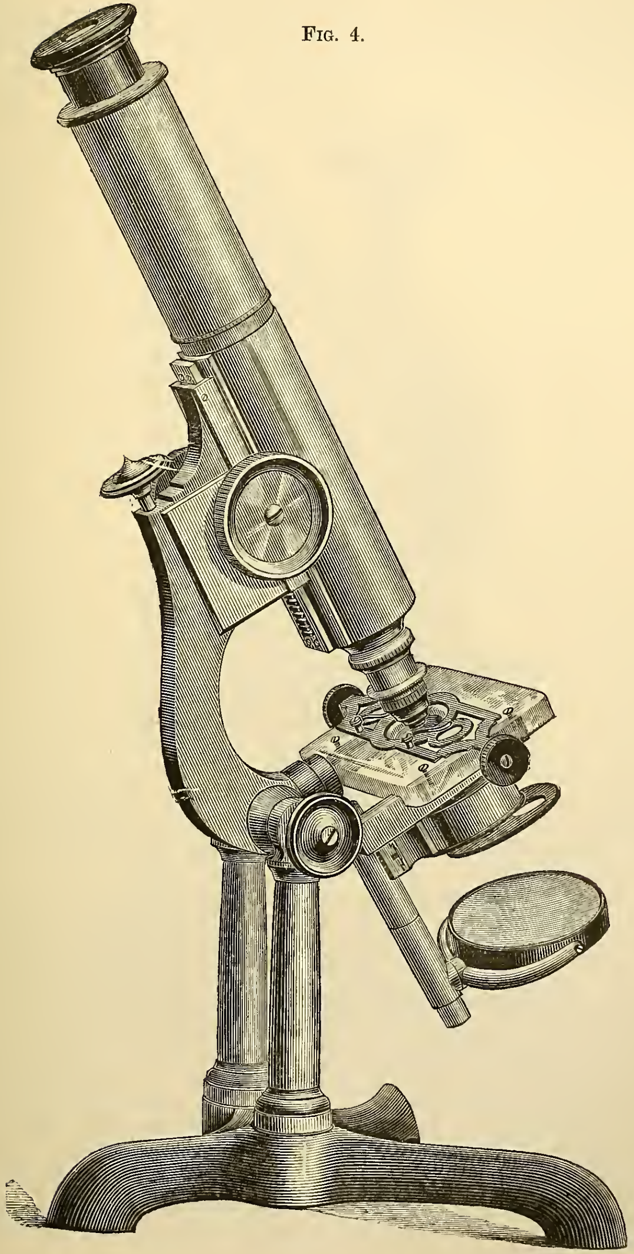
The glass stage and slide-holder are described *infra.*

The chief point of novelty to us is the fine adjustment, which is so simple and effective that we show it in detail in Fig. 5. The drawing of the mechanism is made from Mr. Crouch's stand (Fig. 7) in which the fine adjustment is similar. Messrs. Bausch and Lomb hold a patent for this system of focussing in the United States.

It will be seen that the solid bar A, carrying the optical body B, is suspended on the front ends of the two broad, flat, parallel, tempered steel springs CC, the other ends of which are attached to the limb D. The pressure of the focussing-screw E, by the point at F on the solid bar, forces down this bar, the springs bending sufficiently to allow about $\frac{1}{6}$ inch range of motion downwards from the normal position (as figured). The actual motion of focussing displaces the optic axis slightly, as with the system adopted by Seibert and Krafft (figured and described *ante*, iii. (1880), p. 1047). But this displacement is of no practical moment, except where the Microscope is provided with a rotating stage, or where certain delicate micrometrical measurements are required. This focussing must be regarded as practically free

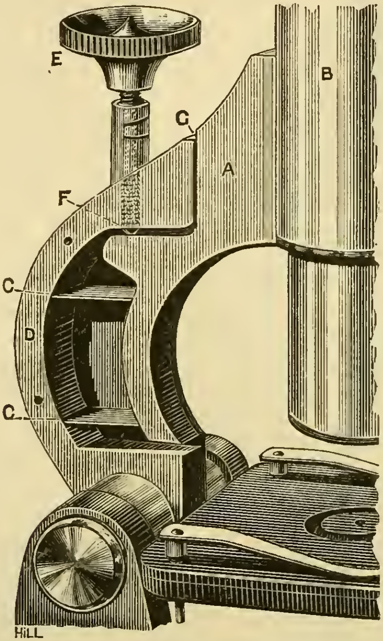
* See this Journal, iii. (1880) p. 1055.

FIG. 4.



from friction, as there are no metal surfaces in contact; the only friction is between the point of the screw at F, where it acts on the bar by pressure. The suspension of the optical body is strictly on the two springs C C. The open space shown at G is free from all

Fig. 5.



contact of the metal faces. The metal plates used on both sides to cover up the mechanism in the limb (removed from the side in our figure to enable the construction to be seen) do not touch the moving surfaces.

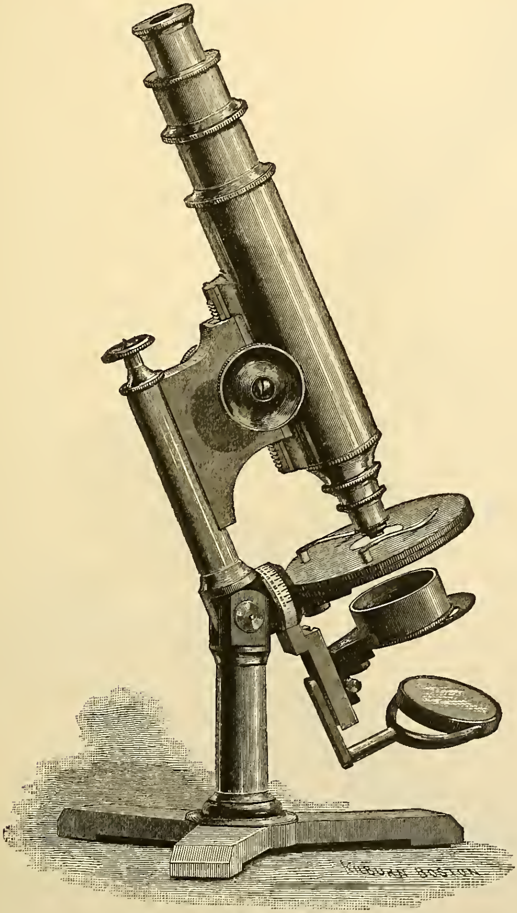
It may also be noted as a novelty that the axis and foot of the Microscope are marked so as to indicate the proper degree of inclination required to place the camera lucida 10 inches above the table.

(2) *Investigator.* The general form of this instrument sufficiently appears from Fig. 6. The main tube has two draw-tubes, which is claimed to be an "entirely new feature in Microscopes, and an unquestionable improvement. It permits the use of the standard length of tube for quick adjustment in outside tube, the same as in instruments without rack and pinion adjustment; it serves also for any low-power objective, and the amplifier can be used in either combination. The outside tube has a broad-gauge screw, and an adapter with the

* The double draw-tube was adopted in a "revolving"-body Microscope constructed by Mr. Browning in 1873; it was figured in the Month. Micr. Journ., x. (1873) p. 234.

Society screw. The stage lies in the same plane as the centre of movement for mirror; it is of brass, and has concentric revolving motion. The mirror-bar swings upon one bearing, to any obliquity below and above the stage for the illumination of opaque objects, and has attached to it a secondary bar, to which the mirror is fitted, and

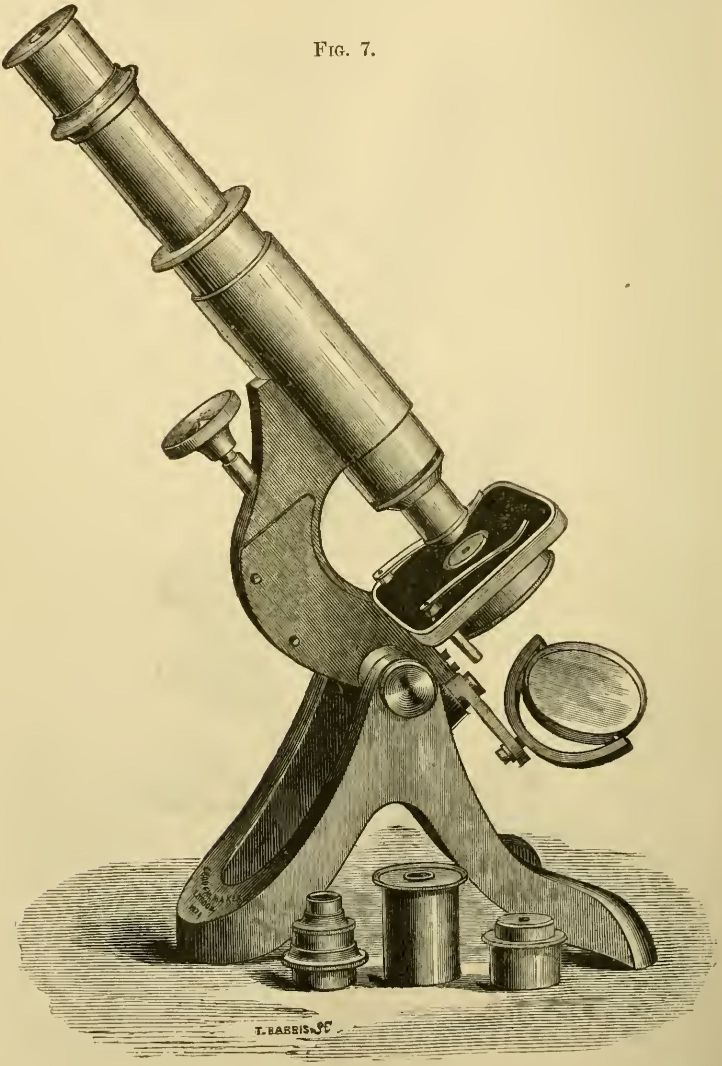
FIG. 6.



which allows the separate use of the latter in any position of the substage. It is provided with a sliding arrangement, whereby the mirror may be moved to and from the object. The substage is adjustable along the mirror-bar, and entirely removable. It contains a diaphragm which may be brought directly under the stage. The ring is of standard size, and is centered by a set-screw."

Crouch's Histological Microscope. — Fig. 7 shows an inexpensive student's stand, as supplied by Mr. Crouch. The foot is of one casting. The stage has a glass bed. A substage slides beneath into

Fig. 7.



a cylindrical fitting, with centering arrangement, as in Hartnack's stand; and sliding cylindrical diaphragms can be pushed up so as to be flush with the upper surface of the stage. The optical body slides in the cloth-lined socket for the coarse adjustment, or rack and pinion can be provided.

The fine adjustment is shown above (Fig. 5).

Sidle's New "Acme" Microscope.*—Messrs. John W. Sidle and Co., of Lancaster, Pa., U.S., the manufacturers of the small "Acme" stand described and figured at pp. 522–3 of vol. iii. (the result of the combined suggestions of Professor J. E. Smith and Mr. Sidle), have perfected a larger stand substantially on the same model.

The binocular prism is contained in a sliding box, in a nose-piece that fits in the lower end of the body-tube by a bayonet-joint. By removing the nose-piece a clear field is given to lenses having the $1\frac{1}{4}$-inch screw, and by screwing into this thread an ordinary adapter with "Society" screw one is prepared for the use of low-power lenses of large apertures. This is an improvement, as most of the binocular stands do not permit of the employment of wide-angled objectives to their best advantage, in consequence of the diaphragms usually applied in the main tube.

The substage swings on a circle of $3\frac{3}{4}$ inches diameter, and is graduated to degrees. It moves along the swinging-bar by rack and pinion. The substage may be centered in the optic axis by two milled heads. This centering arrangement is of new construction, and is contained in the space between the substage ring and the slide, thus doing away with the large ring and set-screws found on some substages.

Tolles-Blackham Microscope.—We gave, in vol. iii. (1880) p. 520, a brief description of this stand, illustrated by a figure. Since that date an improved form has been constructed for Mr. Crisp, which he exhibited at the Society's November meeting, and which we here describe. The figure noted above should be referred to together with those now given.

Mr. Tolles has changed the shape of the foot; it is now in the form of an equilateral triangle, with concave sides and truncated angles, having pads of cork under each end. On the centre of the base a circular plate is turned, and on this rotates a second plate, carrying the pillars of the Microscope; the upper plate is graduated for measuring angles, and can be firmly clamped at any point.

At the back of the vertical disk, a "radial arm," to carry a mirror or other accessory is fitted to rotate laterally concentric with the object.

An extra large milled head slips on the upper part of the pinion of the fine focussing screw, which is intended primarily for use in focussing for micro-photography; for this purpose it is grooved round the edge, so that a thread may be wound on it and the focussing controlled some distance off. For ordinary high-power work, this large milled head adds to the sensitiveness of the focussing; it has been thus applied by Mr. Tolles for many years past.

The draw-tube is nickel-plated, and is said not to become sullied so readily by handling as the usual brass tube. It is graduated, and

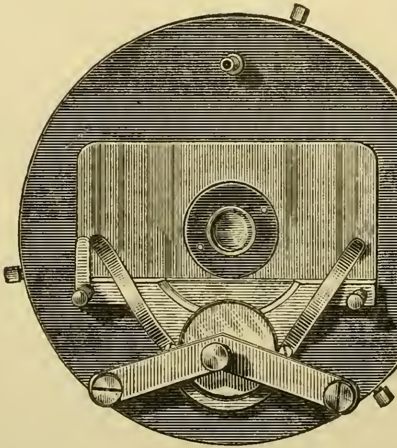
* Amer. Mon. Micr. Journ., i. (1880) pp. 203–4.

has the "Society" screw at the lower end for use with low powers. Mr. Tolles also applies the extra optical combination required for an erecting eye-piece in this position, and also his various forms of amplifiers—simple and compound.

The substage has a slight lateral swivel motion that enables the observer to direct the condenser very exactly radially upon the object, or to use various portions of the minute condensed cone of light, and it also compensates for the varying thickness of the object-slides by which the lateral circular track of the condenser may be rendered not quite concentric with the object. (We are informed by Mr. Tolles that to the earliest forms of his traversing substage-bar he provided special means to secure the exact radial direction of the illuminating pencil concentric with the object with different thicknesses of object-slide; he has forwarded a photograph of a Microscope thus constructed by him in 1873.)

Two stages are supplied that are interchangeable by a simple spring latchet arrangement, clipping them on the same fixed centering ring attached at right angles to the vertical disk. The one stage (*in situ* in the figure above referred to) is shown in Fig. 8, half size.

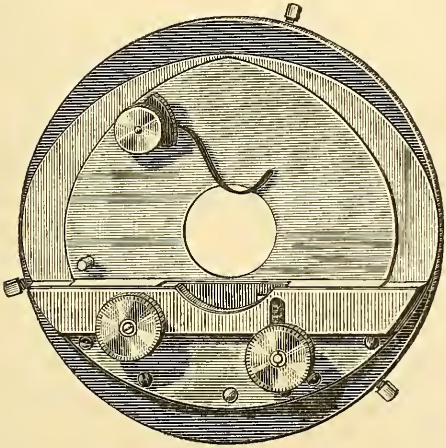
Fig. 8.



It rotates completely. The rectangular plate of German silver is about $\frac{1}{50}$ inch in thickness, and is attached to a glass friction-plate, held against the circular stage by an adjustable spring pressure-point; the thickness of this metal plate forms no hindrance to the use of the hemispherical lens, seen in the centre, which is intended to be used in immersion contact with the base of the object-slide.

The mechanical stage (Fig. 9) presents several points of novelty. The rectangular motions are controlled on the *surface* of the stage entirely within the circumference. The milled head on the right is attached by a pinion to the circular base-plate (milled on the edge) and carries a toothed wheel that moves both plates in the vertical by a side-rack shown in the slot opening; whilst the other one acts on a rack, under the bar in the hollow horizontal track that forms part of the upper plate, and causes this plate only to traverse. The two moving plates are of German silver, each about $\frac{1}{50}$ inch in thickness;

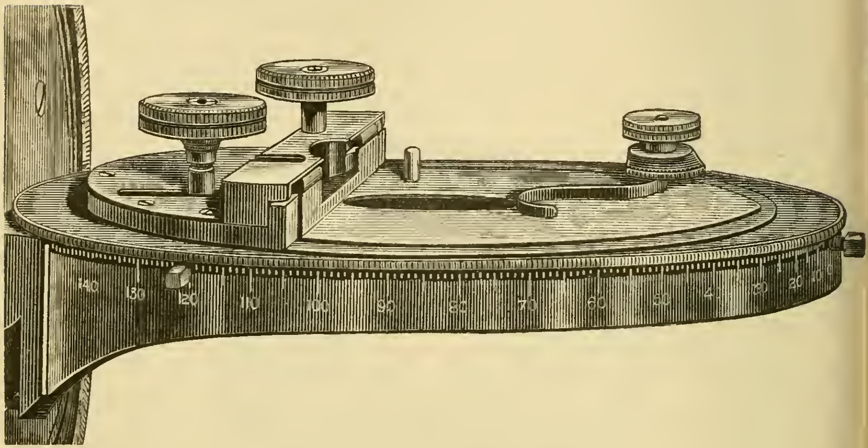
Fig. 9.



the lower one is held on the circular stage by three short pins with spring washers that travel in corresponding slots cut through the stage and forming a triangular support; the upper one lies nearly flat on the lower one, touching merely round the outer edge. The total thickness of this mechanical stage may be better appreciated by a glance at Fig. 10 (*actual size*), in which the ring, graduated on the edge, is the main stage ring, attached at right angles to the vertical disk (shown in part) having within it another one that carries either of the two moving stages figured, and which can be exactly centered to rotate on the optic axis by the three steel screw studs (two of which are seen on the edge). From the upper surface of the moving plates, where the object is placed, the perpendicular thickness is slightly less than half an inch—probably the thinnest mechanical stage ever made to a first-class stand. As no portions of the stage project beyond the circular edge in any position of motion, the complete rotation can be made. The absence of projecting pinions or milled heads is of some advantage in connection with the full radial swing of the substage.

When the Microscope is placed horizontal, the object on the stage is in a perpendicular axis, passing through the centre of the rotating foot; if then a lamp flame be adjusted in a line with the optic axis the rotation of the Microscope on the foot will provide a practically perfect range of oblique illumination on either side. The hemispherical lens, as applied to this stand by Mr. Tolles for immersion illumination, adds greatly to the facility of obtaining effects of obliquity; indeed, he appears to have been the first to distinctly

FIG. 10.



realize the advantages of this kind of illumination, dating back from his first production of immersion objectives, having "balsam angle" greater than 82°.

Reflection from the Inside of Body-tubes.*—In their new form of stand, Messrs. Sidle prevent the formation of a burnished reflecting surface, produced by friction below the eye-piece, by turning an annular groove on the inner surface of the draw-tube, near the top, of such a width that the surface which is exposed to the friction of the eye-piece will not be uncovered, no matter what eye-piece may be used.

This device might (Mr. A. L. Woodward considers) be applied to any stand, at comparatively slight expense, whereas the application of a collar would necessitate either a new and larger body-tube or else a narrower eye-piece.

Whilst on the subject of making this improvement in connection with the eye-piece fitting, we would urge the importance of applying to the various eye-pieces such adapters as will bring the field-lens in each case to the same position in the tube. By this means (as adopted many years ago by Powell and Lealand) the estimation of the magnifying power is facilitated, and much of the inconvenience avoided of refocussing and readjusting when different eye-pieces are used with high-power objectives.

Adaptation of the "Society" Screw to Draw-tubes.—We observe in the various descriptive catalogues of American Microscopes, that

* Amer. Journ. Micr., v. (1880) p. 185.

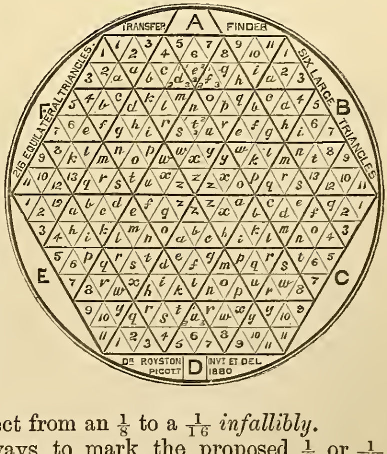
the draw-tubes of all sizes of stands are beginning to be fitted with the "Society" screw, to carry objectives at the lower end. This is a practical innovation, which might be generally adopted, we think, with advantage. The object is to enable low powers—such as 3 inch, 4 inch, or even 5 inch—to be readily used, the draw-tube providing convenient and rapid means of focussing roughly, without the body-tube itself having to be moved higher than the normal position, where the Microscope is well balanced.

Accurate focussing can be obtained with large stands, by the usual coarse rack and pinion motion. The nose-piece of the main optical body (into which the higher powers are screwed) is not found to present any obstacle to the use of the draw-tube.

There is the further advantage in a screw on the draw-tube, that an objective can be applied to produce with the ordinary eye-piece an erecting arrangement, so that a special "erector" may be dispensed with. This, as is well known, enables wide variations in magnifying power with the same objective to be obtained, and is not only serviceable for dissections, but for the examination of gems, large specimens, and low-power work generally. Amplifiers may also be attached to the lower end of the draw-tube.

Dr. Royston-Pigott's General and Transfer Finder.—The following description is supplied by Dr. Royston-Pigott:—The finder (Fig. 11) consists primarily of six large triangles lettered A, B, C, D, E, and F at the margin. Each triangle is divided into thirty-six small triangles lettered or figured. Any triangle is identified by two letters, such as B*z*, E*x*, or F*r*. A platinum disk perforated with a small hole is made to slide or fold over into the position for zero. This is used only for finding objects generally. The triangulated finder is transparent, and is placed so as to occupy the stop in an A eye-piece.

FIG. 11.



Transfer Finder.—Plan.—The finder should just fill the stop of an A eye-piece, which must have a stud to correspond with the notch on the draw-tube, so as to keep the finder vertical in one position, and the notch should go through the eye-tube and draw-tube together.

Use.—To transfer say an object from an $\frac{1}{8}$ to a $\frac{1}{16}$ *infallibly.*

1. Use a standard inch always to mark the proposed $\frac{1}{8}$ or $\frac{1}{16}$ or $\frac{1}{32}$. Place a sharp object *in the centre* by the $\frac{1}{8}$ inch and finder. Then substitute an *inch* objective, and mark the position, say B*z*, on the finder. Upon placing any other object on B*z* with the inch, the given $\frac{1}{8}$ will show it in the middle of the glass.

2. Suppose it is required to find the triangle for a $\frac{1}{16}$. Take

any object in the centre with the $\frac{1}{16}$ and finder, then replace the inch objective, read the finder, say Ex triangle, then on placing any other object with the inch objective on Ex, on putting on the $\frac{1}{16}$ it will appear in the middle of the field.

3. Again, if an object be seen in the finder on Bz with the inch, the object must be transferred to Ex to transfer it from the $\frac{1}{8}$ to the $\frac{1}{16}$, and so on for a $\frac{1}{32}$. Say the inch finds it on Fr when it was central in $\frac{1}{32}$. Then if any other object be placed on Fr by the inch, it will be seen central by $\frac{1}{32}$, and Ex for $\frac{1}{16}$ will be Fr for $\frac{1}{32}$.

Use as a General Finder.—If the clip on the stage slides down and closes up so as to occupy the place where the object would be, a small piece of platinum wire is to be let in and riveted; then a small hole as fine as a watchmaker's pivot is to be drilled or punched through it. The position of this punctum should be a *mean* position, so as to correspond with the centre of stage motion. If this cannot be done, a small piece of brass is to fold over instead, carrying the platinum hole.

To use the Transfer Eye-piece.—Place an object with the inch on the centre of field; note the triangle where the hole is seen on being folded over into the field of view, say it is (At). Then when the hole is again placed at At the object will be in the centre of field, and if it be put on Bz $\frac{1}{8}$ will find it, and if it be put on Ex $\frac{1}{16}$ will find it, and if it be put on Fr the $\frac{1}{32}$ will find it.

Angular Aperture—a Correction.—In a recent number of the 'American Journal of Microscopy,' Mr. Bragdon alluded to a $\frac{1}{10}$ oil-immersion, by Tolles, stating its aperture to be 148° in a medium of index 1·525, which would very nearly = 1·5 "numerical." Mr. Bragdon has since informed us that "148°" was a misprint for "141°," so that the $\frac{1}{10}$ in question has a numerical aperture of about 1·43.

Low Powers of Large Aperture.—We learn that Mr. Tolles, of Boston, has recently completed a $\frac{2}{3}$ objective of 0·58 numerical aperture (= 70° "angular" aperture), and that even with this large aperture the field is fairly "flat." It is said to resolve *P. angulatum* with oblique light *direct* from the lamp (that is, without any form of condenser); whilst, with a concave mirror used in the axis, it exhibits the lines on ordinary specimens, giving resolution in all parts of the field.

Notwithstanding its aperture, it has been constructed for use on the usual Microscopes having the "Society" screw. We believe that all previous attempts made in America to secure so large an aperture with this focus have required a larger gauge of screw, so as to permit the utilization of a back lens larger than the gauge of the "Society" screw.

Gundlach's Homogeneous-immersion Objectives.—Mr. Ernst Gundlach has recently forwarded to Mr. Curties a new $\frac{1}{8}$, constructed on a formula by which he states he will be able to secure longer working distance and an angle of aperture approximating to 180° in a medium of index 1·52 (that is to say, a numerical aperture approaching 1·52). He claims for the $\frac{1}{8}$ an angle of 140° (= 1·43 "numerical" nearly).

Secure Method of Setting the Front Lens of Oil-immersion Objectives.—Mr. J. Mayall, junr., sends us the following note communicated to him by Mr. Wenham:—

"The method usually employed to set the minute fronts of oil-immersion lenses, has been to 'burnish them in,' that is, to fit them exactly into the cell, leaving a thin rim of metal projecting round the lens, and while the setting is running in the lathe laying this over the edge of the glass, which should be slightly chamfered. With large eye-piece lenses this is an easy and certain operation, but with lenses less than one-eighth of an inch in diameter, it is one of the most difficult and delicate operations in optical manipulation. Not only is there some risk of fracture, but if at the time that the metal grips the glass, the surface should get out of truth from the tilting of the lens, this cannot afterwards be forced to run true, as the pressure required would certainly cause fracture; the only remedy is to cut out the lens and try again. I have seen a great number of minute lenses, that have been 'burnished in,' running out of truth simply because there is no absolute control over the operation; and to make an oil-tight fit, the brass, or other metal equally hard, must bear heavily on to the fragile glass, with the liability of distorting its figure.

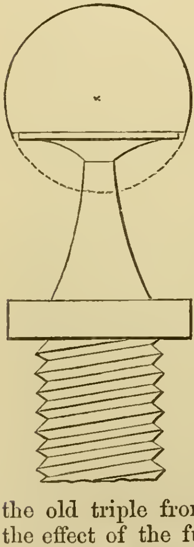
"Many years ago I set some minute eye-piece lenses in the following manner:—I turned the cell clear out, so that the lens would drop easily through. I then heated the cell, and with a conical-pointed copper wire, well tinned, and a fragment of rosin for a flux, I twisted the wire round till a ring of tin was well fused round the hole. I then turned the tin lining out true, to form the cell and bed for the lens, leaving the projecting ridge necessary for burnishing. This operation was performed with an ivory stylet lubricated with moist soap. Before the finishing touch is completed, if the face of the lens is seen to run out of truth (ascertained by the usual 'candle' test), the soft metal will yield to a moderate pressure applied on the proper side; the burnishing may then be completed without fear of the lens wabbling, and, finally, the edges neatly finished with a turning tool. I have set the front lenses of objectives this way, and the soft tin plies so well round the glass that no leakage occurs with any kind of oil or spirit; and lenses thus mounted may be pushed out from the back of the cell, for alteration or repair, without risk of fracture, as the portion of tin that has been laid over is raised up again without the application of a dangerous degree of force.

"The volatile oils or spirits used for immersion lenses, act energetically in softening or dissolving either Canada balsam or shellac, and it will not answer to employ these substances for rendering them oil-tight.

"For the purpose of making a leaky joint tight, I have found ordinary sulphur answer perfectly, as it is not acted upon by any cold immersion fluids that can be used, and as its melting point is about 220° Fahr., the heat required in its employment will not injure the coat of lacquer on brasswork. In order to cement a front lens oil-tight in its cell, it is sufficient to place this, with lens fitted in position, on to a hot plate, and drop a fragment of sulphur on the lens, raise the heat till the sulphur melts and flows round the edge. By capillary attraction it runs into the joint. Although the melted sulphur is very fluid, yet it has a singular disinclination to attach itself, or spread on a polished surface of glass; and this property quite prevents it from creeping over the back of the lens, as balsam or shellac will do, and when cold the button of sulphur on the front may be easily picked off with a needle point, leaving the surface of the glass clean.

"Fronts extending beyond the hemisphere have been proposed by Professor Stokes. I do not at present pretend to give a comparison of any degree of advantage or superiority over the common hemispherical front, as I have not yet tested the relative performances of both, as applied to the same object-glass. I have first to state that there is no great difficulty in constructing such lenses. In fact, from the mode that they can be worked in the mould, the figure of this form of lens is more likely to be perfect than a hemisphere. Having ascertained the thickness to be given from the flat face to the top of the sphere, a piece of glass polished on one side is flattened down to the thickness, then cemented on to a suitable chuck, on which the finished lens will appear, as in Fig. 12. In working and polishing, the sphere may be rolled round in the tool till the holding chuck and handle is carried out at right angles to the axis of the mandril of the lathe. We cannot go to this extent with a hemispherical lens without working off the edge too much, but the more a *sphere* is turned about in every direction, the more perfect the figure becomes.

Fig. 12.



"The difficulty has hitherto been to mount these balloon lenses securely. The plan that has been adopted is to set them on a plate of thin cover-glass, with Canada balsam or other cement, and burnish the plate in at the edge. The whole arrangement is thus so fragile that, after the balsam is hard and brittle, the mere act of wiping the front will probably start the surfaces, and the least pressure on the object-slide (which even the most careful manipulator cannot always avoid) will dislodge the lens, besides the objection of somewhat impairing the finest definition by two additional surfaces, even when cemented. I have seen a great number of instances wherein the old triple fronts made by Ross, as in Fig. 13, in order to gain the effect of the full hemisphere, have had the thin flint disk broken in by contact with the slide. In mounting the balloon front, I substitute a disk of well hammer-hardened metal, in lieu of the glass-supporting plate, as shown by Fig. 14. After the lens is polished, it is removed from the holder and its convex side cemented on to a ring-chuck with shellac, and the flat surface set true by the 'candle-flame' test. This can be quickly and easily done by warming the chuck with a spirit lamp. A groove is then turned round the corner of the lens, as shown, by means of a keen splinter of diamond, and the supporting plate turned to fit the groove, which plate is afterwards cemented or burnished in the front of the setting. To avoid risk of pushing the lens in by pressure, the face should not be quite flush with the front of the plate.

Fig. 13.

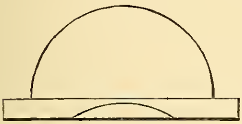
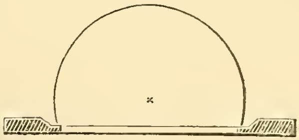


Fig. 14.



"To cement the lens into the plate, lay this on a piece of tissue paper set on the hot plate, put a fragment of sulphur into the ring, and the lens on the top of this. When the sulphur has melted, press the lens well down into the ring. After the whole has cooled, the surplus sulphur comes off by a pull with the paper. In turning out the groove at the corner of the balloon lens, there is but little risk of splintering the glass, if a suitable diamond point is used. The small fracture in the lens shown, was occasioned by the use of a ring emery grinder, rather too small, intended to take off the rough cut of the diamond; but I consider this after smoothing operation unnecessary, as it is more hazardous to use than the diamond itself.

"I have found the best way of mounting these diamond splinters to be thus: Take a short piece of copper wire, and split the end down about one-eighth of an inch with a watch-spring saw; open out the split and anneal the end by heating it red hot. Lay the splinter of diamond on one of the open sides, sticking it on with a touch of Canada balsam. When the point appears fairly projecting in the direction required, close the split together with pliers, well pinching it on to the diamond; this becomes imbedded in the soft copper. Finally, by means of the blow-pipe and borax, run silver solder into the slit, and thus the diamond will be very securely fixed."

New Homogeneous-immersion Fluid of 1·5 Refractive Index.—Mr. Charles H. Bassett, of Boston, U.S.A., has recently communicated through Mr. Tolles a formula for a new immersion-fluid, which has proved successful with Mr. Tolles's high-angled homogeneous-immersion objectives. We quote from Mr. Bassett's instructions:—

"The formula for the new 'homogeneous-immersion fluid' of refractive index 1·5 is:—

Schering's chloral hydrate, in crusts	grs. 485
Bower's pure glycerine	grs. 70

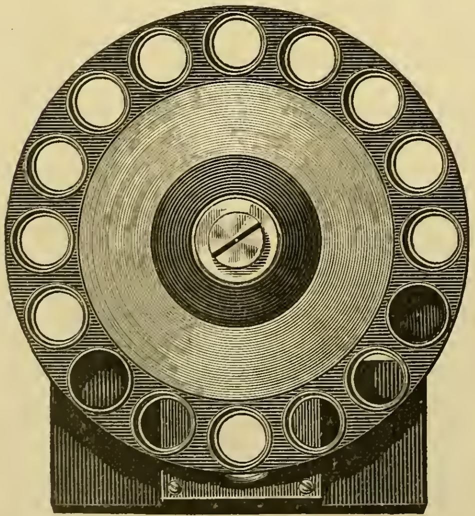
Mix, and dissolve in an open-mouthed bottle by means of a water bath.

"No special manipulative skill is required in the preparation of this fluid; due care, however, should be exercised in *weighing* the ingredients, also in seeing that the chloral is of Schering's manufacture, and in *crusts* instead of crystals; the glycerine should also be *pure.* Place the articles in a thin open-mouthed bottle, which should be partially immersed in cold water contained in an ordinary saucepan. Heat the water to the boiling-point, and continue the boiling until the chloral is dissolved, which will occur in ten or twelve minutes. When cold the mixture is ready for use. It can be readily removed from the objective and slide with cold water, or if in haste, equal parts of methylated alcohol and water will act more promptly."

We understand that Mr. Bassett has for some time applied his practical knowledge as a chemist to the problem of discovering a suitable fluid for homogeneous immersion. He places the above result of his labours before the Society in the belief that it will be found of good service.

Bausch and Lomb Optical Company's Slide-holder. — This (see Fig. 4) is a substitute for a mechanical stage. It consists of a German-silver plate of very light weight, moving on a strong glass plate which forms the immovable stage. Only four small points of the metal plate touch the top of this glass plate, while two prolongations of the former, bent downward and backward and acting as springs, press against the under side of the glass plate with just sufficient force to keep the slide-holder in position and to prevent it from slipping off when the Microscope is inclined. Two small knobs facilitate the handling of the slide-holder. It is claimed that the arrangement exceeds in smoothness and evenness of motion the ordinary form of movable glass stages, and at the same time, while the movable part is of less weight, the glass plate can be of sufficient strength to guard against easy breaking. The glass stage has later been made circular (and thinner), and the slide carrier revolves.

Fig. 15.



Beck's Rotating Holder for Rubber Cells. — Fig. 15 (half size) shows this holder (referred to at p. 1041, vol. iii.), which forms an addition to the list of microscopical appliances in which ebonite is used.*

* See this Journal, iii. (1880) p. 1082.

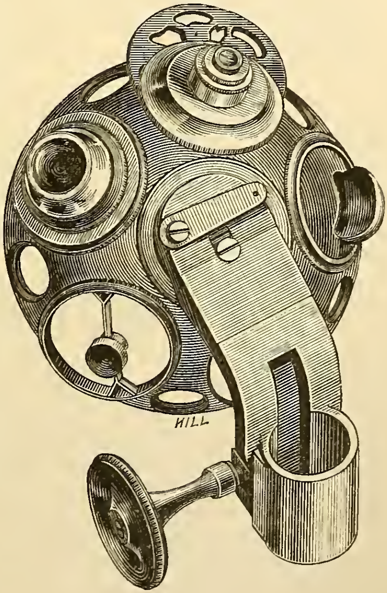
The rectangular plate (at the lower part of figure) is attached to the stage of the Microscope by the usual spring clip, and is adjusted so that a cell is in the field of view. The upper, circular, tablet—in the openings of which the cells are placed—can then be rotated, and the contents of the whole sixteen cells passed in review.

For public exhibition, at soirées, &c., this rotating holder will be found very convenient. It is very light, and not easily injured.

Wallis's Calotte Substage.—At the December meeting, Mr. G. Wallis exhibited a Microscope of his own design and construction, the chief novelty of which was the substage, shown in Fig. 16.

The substage is formed of a strong brass calotte, upon which Mr. Wallis applies (1) a silver side reflector (shown on the right of the figure), (2) an achromatic condenser with its system of diaphragms, (3) a paraboloid, (4) a dark well, (5) a clear opening for use without special apparatus. On the inside of this calotte a section of another one is mounted to rotate on the same centre, and carries selenites and ground and tinted glasses, and similarly a third carries the polarizer; so that either or both can be rotated and used beneath the achromatic condenser. The whole is mounted on a pinion at an angle of 45° on a substage arm (moved by rack and pinion), so that the rotation of the outer calotte figured will bring each piece of apparatus into the axis of the Microscope, where a spring stop holds it. A fixed washer between the plates prevents the motion of the one being communicated to the others, each acting independently.

FIG. 16.



Mr. Wallis claims that in this manner all the substage apparatus usually adapted to the Microscope can be carried ready for immediate service, thus dispensing with the trouble of applying each separate accessory whenever required. He uses a similar calotte nose-piece carrying sundry objectives, and states that he leaves all his apparatus thus attached to the Microscope in constant readiness for any investigation he may desire to make.

Centering Nose-piece as a Substage. — Mr. E. M. Nelson has suggested that for use on small Microscopes, the ordinary centering nose-piece can be easily applied as a substage (see Fig. 17), thus providing convenient centering motions with which small instruments are not usually supplied by opticians. The optical part of a $\frac{4}{10}$ objective then forms an excellent condenser; for this purpose it should be fitted with the shortest possible adapter, so that diaphragms may be used close beneath the back lens.

Mr. Nelson has also suggested the application of diaphragms beneath such a condenser in an annular disk-fitting swinging sideways on a pivot, the disk having a ledge within, on which one, two, or three diaphragms of various shapes may be placed together, and rotated by a milled edge (shown in the figure projecting beneath with shaped handle serving to move the disk out of the axis to change the diaphragms). The practical management of the diaphragms is obviously of the first importance in obtaining variety of effects of light with a condenser in the axis. Mr. Nelson has found the most useful series of diaphragms to be those represented in Fig. 18, in which *a* may be regarded as a type shape for one pencil of light, and *b* for two—at right angles. The superposition of stops like *c* will cut off more or less of the central light, while *d* will cut off more or less of the peripheral zone; *e* is a combination in which the square opening is intended to utilize the most oblique pencil required for the resolution of very fine lines, &c., whilst the small circular aperture is calculated to give a beam of light for the resolution of less difficult markings on the same object at right angles—for instance, on *Surirella gemma*. It is advisable to have a variety of sizes of *c* and *d*, as upon these depend most of the difficult resolution to be obtained by using the condenser in the axis.

Fig. 17.

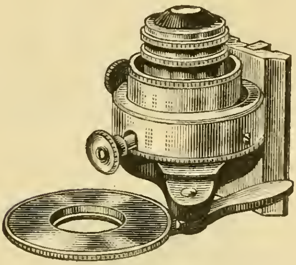
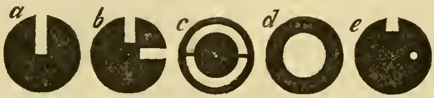


Fig. 18.



Of course the above arrangement for diaphragms can be applied to any form of condenser, and is not confined to the centering nose-piece.

Mayall's Spiral Diaphragm for Oblique Illumination.—At the Society's December meeting, Mr. J. Mayall, jun., described a spiral diaphragm, which he had devised as a convenient means of obtaining oblique illumination in connection with high-angled condensers to be used in the axis of the Microscope.

If a slot diaphragm (as shown in Fig. 19) be fixed close beneath the large lens of a high-angled condenser, such as those lately constructed by Powell and Lealand, and by Zeiss, the rotation under it of a diaphragm having a spiral opening (as figured) will provide a pencil of light at *varying* degrees of obliquity throughout the range of aperture of the condenser. The azimuthal direction of the incident pencil will of course be controlled either by rotating the *object* or the *condenser* carrying the diaphragms; whilst the rotation of the spiral on the fixed slot will not change the direction in azimuth, but only in altitude, so far as the aperture of the condenser will permit.

Fig. 19.

The diaphragms hitherto applied for this purpose have for the most part had but a very limited range of action in *varying* the angle of oblique incidence of the illuminating pencil; indeed, with the exception of Professor Abbe's traversing diaphragm plate fitted to his recent forms of substage condensers, we are not aware that any efficient means for this purpose has been devised. Professor Abbe's plan requires a special horizontal rack and pinion made to the substage to allow the free motion of the diaphragm.

High Amplifications.—References have been made by a lady correspondent in recent numbers of the 'American Journal of Microscopy,' to an amplification of upwards of 20,000 diameters obtained with a $\frac{1}{6}$ objective using an eye-piece of $\frac{1}{50}$ equivalent focus. On the usual assumption that a 1-inch objective gives a magnification of 10 linear, a $\frac{1}{6}$ would give 50, and a $\frac{1}{50}$ eye-piece 500: the combined amplification would therefore be $60 \times 500 = 30{,}000$ linear. A few instances of practical results obtained with high amplifications cannot but make us feel sceptical of the value of the definition obtained with a $\frac{1}{50}$ eye-piece.

Sir John Herschel, in his 'Treatise on Light,'* mentions having "viewed an object *without utter indistinctness* through a Microscope by Amici, magnifying upwards of 3000 times in linear measure."

In the very early days of the collodion process in photography, Mr. Wenham exhibited a micro-photograph of *P. angulatum* magnified 15,000 linear: it is no disparagement to the photograph (a copy of which we have recently inspected), to say that it is not remarkable for distinctness. It was produced with the first compound achromatic $\frac{1}{25}$ ever made in this country; and the lens coming from the hands of an amateur optician, and the photograph being produced by the same amateur photographer, the result was then regarded as an almost marvellous specimen of practical skill and ingenuity.

Some thirteen or fourteen years ago, Hartnack had a micro-photographic transparency on ground glass of *P. angulatum* exhibited in his *atelier* in the Place Dauphine, Paris. The magnification was about 3000 linear; the image was well defined to the edges—about 16 inches square—and was produced with one of his then best No. 10 immersions.

* Encyc. Metrop., p. 581.

In 1867, Dr. Woodward, of Washington, forwarded to Dr. Maddox for exhibition to the Society, a series of micro-photographs of *Podura* scales, and various other test objects produced with sundry objectives, notably Powell and Lealand's $\frac{1}{50}$, $\frac{1}{25}$, and $\frac{1}{16}$ dry lenses. The amplifications did not exceed 2100 linear. Dr. Maddox then remarked that he believed "the *Podura* scale had never yet, in this country, been photographed by a $\frac{1}{50}$." The *Navicula rhomboides*, by Wales's $\frac{1}{8}$ and amplifier, magnified 800 linear, was especially admired.* Shortly afterwards, Dr. Woodward presented to the Society a large series of micro-photographs of Nobert's 19-group test-plate, and other test objects—the direct amplifications not exceeding 2000 linear.

At various dates micro-photographs have also been brought before the notice of the Society by Dr. Maddox, Dr. Woodward, Count Castracane, Mr. S. Wells (of Boston), and others, and the direct amplifications have rarely exceeded 2000 linear.

In 1868, Mr. Charles Stodder, of Boston, having access to a number of the presumably best objectives in America, was content to specify his own magnifications as not exceeding 1062 linear (though he referred to 6000 obtained by Messrs. Sullivant and Wormly),† and he particularly commended the performance of Tolles's $\frac{1}{6}$ immersion, as "the best on record"—and yet the magnification was only 550 linear for the resolution of Nobert's 19th group.‡

It is to be supposed that experienced microscopists like these have in every case sought to do full justice to the objectives in their hands, and it may be noted particularly that with so difficult an object as the highest group on Nobert's 19-group plate, Dr. Woodward, down to the latest date on record, has limited his micro-photographic operations to *less* than 2000 linear of *direct* amplification. His more recent series of micro-photographs comprised *A. pellucida*, both dry and in balsam, the magnifications hardly exceeding 3000 linear, though the objectives included $\frac{1}{25}$, $\frac{1}{16}$, and $\frac{1}{8}$ immersions of Powell and Lealand, $\frac{1}{25}$ and $\frac{1}{18}$ immersions, and $\frac{1}{10}$ oil-immersion of Tolles, $\frac{1}{10}$ glycerine immersion of Spencer, $\frac{1}{8}$ and $\frac{1}{12}$ oil-immersion of Zeiss. The last objective named he regarded as the most powerful "resolving" lens he had seen up to the date of his communication (October 1879). Dr. Woodward has then been contented with about 3000 linear to exhibit the *best* definition of the objectives in the well-known official collection of the Army Medical Museum at Washington.

At p. 821, two micro-photographs of *P. angulatum*, by Günther, of Berlin, were referred to; they were produced with Gundlach's No. VII. immersion, the direct magnifications respectively 2000 and 5900 linear—obtained by receiving the images at conjugate distances of 1 metre and 3 metres (nearly). These excellent prints have since been received, together with one of *Frustulia saxonica* in balsam, magnified about 5000 linear (enlarged from the original photograph), showing an appearance of beaded structure even more palpably than

* Quart. Journ. Micr. Sci., No. xxix. (1868). (Proc. R. Micr. Soc., p. 63.)
† Amer. Journ. Sci., Jan. 1861.
‡ See reprint of Mr. Stodder's paper on "Nobert's Test-plate," &c., Quart. Journ. Micr. Sci., No. xxxi. (1868) pp. 131–8.

in Mr. S. Wells's micro-photograph exhibited at the Society in 1876.*

If, among the above results, we select as a standard Dr. Woodward's micro-photographs of *A. pellucida*, produced with Zeiss's $\frac{1}{12}$ oil-immersion, we shall find that (apart from the use of an amplifier) the magnification was obtained by receiving the image at a conjugate distance equivalent to the use of an eye-piece magnifying 25 linear—that is to say, the $\frac{1}{12}$ would give 120, and this combined with an eye-piece of 25 would produce 3000. An eye-piece of 25 being of $\frac{2}{5}$ equivalent focus, it follows that the eye-piece ($\frac{1}{50}$) referred to by the lady correspondent is just 20 times as strong (500 as against 25) as that which Dr. Woodward thought most effective to exhibit the best resolving power of Zeiss's $\frac{1}{12}$.

Applying similar reasoning to Mr. Charles Stodder's example, i. e. Tolles's $\frac{1}{6}$ giving 550 linear, we learn that he obtained his "best result on record" with an eye-piece of about 9 linear, that is, less than 1 inch equivalent focus—a startling difference when compared with a $\frac{1}{50}$ with its 500 linear.

Mr. Dallinger referred to 10,000 or 15,000 diameters in his lecture at the Royal Institution and at Cambridge (1879), but when describing his results in his paper to this Society,† he pointedly stated that his *best* results were obtained with Powell and Lealand's new formula $\frac{1}{8}$ immersion, and his magnifications were less than 4000—that is to say, his eye-piece power did not exceed 50 linear.

Here, then, we have roughly collected a few instances of practical results, to which we draw special attention, as clearly indicating that in the opinion of some of the best living manipulators with the Microscope, amplifications beyond 5000 or 6000 linear exhibit no further visible resolving power; indeed we think these figures are far in excess of the practically useful limit, and that from 2000 to 3000 linear would amply represent the limit of visible resolving power.

In America, more than one professed microscopical expert—notably Mr. John Phin, editor of the 'American Journal of Microscopy,'‡ and "Carl Reddots," §—has lately alluded to 80,000 or 100,000 diameters as within the power of his appliances. With the evidence of micro-photographs before us, we must regard any such magnification as of no practical scientific value. We say this the more advisedly from the fact that we have tested some of the finest specimens of American optical work, including the choicest objectives from the hands of Tolles, Spencer, and Wales; we have also tested the best lenses we have met with of Powell and Lealand, Zeiss, Hartnack, Prazmowski, Nachet, Seibert and Krafft, Bénèche and others, and our conclusion is, that the use of any such eye-pieces as $\frac{1}{50}$ cannot be regarded as anything more than microscopical eccentricity, originating probably from that very common popular error of making the value of a Microscope to depend exclusively upon its magnifying power.

* Mon. Micr. Journ., xvi. (1876) p. 169. † Ibid., xiv. (1875) pp. 105–8.
‡ Eng. Mech., xxxi. (1880) p. 469. § Amer. Mon. Micr. Journ., i. (1880) p. 39.

Highest Magnifying Powers.*—Mr. A. Y. Moore also refers to the same subject under this title.

It is well known to all practical microscopists that the magnifying power of an objective may be increased by eye-piecing to a certain extent, with a continued gain in resolving power. When the limit of resolving power is reached the magnifying power may be further increased, but nothing is gained, except in the apparent size of details already shown. After this comes a period in which the magnifying power may be increased almost indefinitely; but it is now very noticeable that the resolving power is impaired. The aberrations of the objective interfere greatly with the image. In fact, it is here that a lens is frequently said to "break down."

These three stages may be conveniently studied in an ordinary cheap $\frac{1}{4}$ of 100°. With an amplification of 300 diameters such a lens should easily resolve *P. angulatum*, but try as best we can, the lines of *Surirella gemma* will fail to be seen. Now, if a higher eye-piece be applied, giving a power of 500 diameters, this diatom may be resolved. Supposing this to indicate the limit of resolvability of the object, a still higher eye-piece may be used; but the resolution is simply shown larger. This period probably will extend to 1000 diameters, but if increased much beyond this less is seen at each increase of power.

The extent to which these three stages may be carried is, of course, dependent upon the quality of the objective and its angular aperture. In testing objectives the magnifying power should be carried to the second stage, for a lens is frequently defeated simply because the visual angles subtended by the lines (or dots) are insufficient for recognition by the eye.

In a recent article in the 'American Journal of Microscopy' a magnifying power of 100,000 diameters is mentioned, obtained by means of a Wales' $\frac{1}{15}$. From the fact that *P. angulatum* was the extent of its resolving power, it is seen that the lens was far into the third stage of its magnifying power. Any such increase of power is, so far as practical work is concerned, useless; but the second stage is what we need and want. Frequently details are seen, but are so small as to tire the eyes; while if enlarged by a higher eye-piece fatigue is prevented.

Mr. Moore suggests the question, What is the highest power ever attained and used *without* losing resolving power, and what objectives are best suited to yield such powers? Will a $\frac{1}{25}$ or $\frac{1}{50}$, with lower eye-piecing, give better results than a $\frac{1}{6}$ or $\frac{1}{10}$ with high eye-pieces and the magnifying powers the same? He is only able from personal experience to give the result of using a $\frac{1}{50}$ eye-piece, with a $\frac{1}{6}$ objective of "180°" (or 100° "balsam angle"), giving a magnifying power of 32,500 diameters. With this he was able to see the last three diatoms of the balsam Möller Platte clearly resolved. The lines of No. 20 did not look exactly like "the pickets on a fence," but more like a lean horse's ribs. The eye-piece was not certainly *easy* to use, and sunlight was necessary to see anything at all.

* Amer. Journ. Micr., v. (1880) pp. 174–5.

Origin of Homogeneous Immersion. — In describing a new diatom * (*Navicula synedriformis*), the Abbé Castracane mentioned that he had made use of a homogeneous-immersion objective of Zeiss, "the principle of the construction of which is due to the celebrated professor G. B. Amici, but the realization to Professor Abbe."

On this statement Professor Abbe writes to us as follows:—

"My sincere estimation of the prominent merits of Amici—whom I consider to be the very father of modern microscopical optics—need not prevent my pointing out that it is incorrect to ascribe the homogeneous-immersion method to him.

Amici, it is conceded, first applied *oil* immersion, but the use of oil, by itself, does not constitute *homogeneous* immersion.

Amici did not aim, and indeed at that time could not have aimed, at the specific advantage of an immersion fluid being *as near as possible*, in refractive and dispersive powers, to the crown glass. Some of his oil lenses require, for good correction, a liquid of considerably *less* and others a liquid of considerably *higher* refraction. From what is known of Amici's oil lenses it is clear that he availed himself of the different refractive powers of various oils and mixtures of oils for obtaining the best correction of his lenses *after he had finished them*, but did not direct his work to any definite refractive index of immersion fluid *prescribed previously*, except perhaps in favour of water immersion. This is so natural that it would be unintelligible if Amici had proceeded otherwise; he *could* not aim at the peculiar optical benefits attendant upon the index 1·50 in comparison with 1·45 or 1·55, because it would have been utterly impossible to utilize it practically at that period. This requires a refinement of technical art which was not attained by the manufacturers of immersion objectives until a much later time.

The essential fact, in the principle of homogeneous immersion, is the increase of optical performance obtained from the total suppression of spherical aberration in *front* of an objective, and it was Mr. J. W. Stephenson who, in his first communications with me, expressed the opinion that doing away with the anterior aberration would improve the defining power, and especially would afford *very favourable conditions for further increase of aperture*, and suggested that the matter should receive an exhaustive theoretical and practical investigation by Mr. Zeiss and myself.

This suggestion, which had not been previously made (though it is very self-evident *now*, as is always the case after a thing has been done), is the true origin of the homogeneous-immersion method, and the basis of the superior performance of objectives of this kind."

The Essence of Homogeneous Immersion.—In a subsequent note Professor Abbe gives the following further explanation of what is the essence of homogeneous immersion from the optical point of view:—

"The peculiar performance of the non-achromatic, approximately hemispherical, front lens which is always used for wide-angled systems (the invention of which by Amici is in my opinion the very

* Accad. Pontif. de' Nuovi Lincei, xxxiii. Sess. II., 25 Gennaio, 1880.

basis of the progress of the Microscope in the last forty years), is characterized by the circumstance that by this form of construction the refractive action of the first *spherical* surface of a system may be obtained, either free from any spherical aberration, or with a very harmless kind of aberration, which admits of exact correction at the upper parts of the system. But there remains still a considerable aberration affecting the pencils before they reach the spherical surface on their passage from the radiant to the medium of the front lens. In the ordinary case of a crown front this aberration depends solely on the *thickness* of the layer of deviating refractive index (air, water, &c.), by which the pencils are admitted, and on the difference, defect or excess, of the refractive index of this layer from the refractive index of crown glass, i.e. on the working distance and on the prescribed working medium of the system. In high and even moderate powers working distance must always be a perceptible fraction of the focal length. When an objective works through air, and in less degree when it works through water or glycerine, the aberration in front bears a considerable proportion to the total spherical aberration occurring within the system, and in the case of a wide-angled lens it is by far the most obnoxious part, for these two reasons: because it affects the cone of rays where it has its maximum angular extension; and because every residual passes to the microscopical image with the total amplification of the objective.

Owing to the former circumstance the anterior aberration is subjected to a very disproportionate increase from the axis to the external parts of the cone as soon as we deal with wide apertures. Whilst in the case of small angles the spherical aberration may be expressed with sufficient approximation by a single term, varying with the square of the inclination to the axis, the anterior aberration of a wide-angled system is composed of many terms varying with the successive even powers of the angle, all of which up to the eighth and tenth power acquire considerable values in respect to the most oblique rays. An aberration effect, the components of which are so very disproportionate, cannot be exactly balanced by opposite (negative) aberration at the upper surfaces of the system where the pencils are contracted to much narrower angles, for these narrower pencils do not admit sufficiently large terms or components increasing by the eighth or tenth powers of the angle. The correction of the anterior aberration must therefore be effected by a rather coarse method, balancing the higher terms by an *excess* of lower terms of opposite aberration at the posterior lenses. This method, of course, cannot afford a *uniform* correction of the whole pencil from the axis to the marginal rays; there will always remain an uncorrected residuum which rapidly increases with increasing aperture, and which appears in the image amplified by the total system as has been indicated above.

This residuum of anterior aberration, which is incapable of correction, and the regular chromatic difference of spherical aberration, are the two principal difficulties attendant upon very large aperture angles. Any non-homogeneous working medium (air, water, &c.), being supposed, there is a maximum angular aperture which cannot be surpassed without undergoing a perceptible loss of definition provided a certain working distance is required.

Withdrawing now the front aberration by an immersion fluid which is equal to crown glass in refractive power, and withdrawing it *for all colours at the same time* by selecting a fluid similar to crown glass in dispersive power likewise, will at once remove the difficulty. Consider for example an aperture of 1·25 (numerical). Water being prescribed as immersion fluid, the front aberration would affect a pencil of 140°, containing rays up to an obliquity of 70°, and with strong glycerine of 1·45 this latter angle would remain 63° still. Substituting a medium which performs like fluid crown glass, the same pencil (contracted to the equivalent angle of 112°) will be admitted to the front lens without any aberration, and owing to the performance of the Amici type of construction, may be made to emerge from the curved surface of the front lens without any detrimental aberration, but contracted to an angular aperture of 70° to 90°. The first notable spherical aberration of the pencil then occurs at the anterior surface of the *second* lens, where the maximum obliquity of the rays is considerably diminished already.

A numerical aperture of say 1·25 represents a water angle = 140°, a glycerine angle of 126°, and a crown-glass angle of 112°. If, now, such an objective of 1·25 should be made for working with water

Fig. 20.

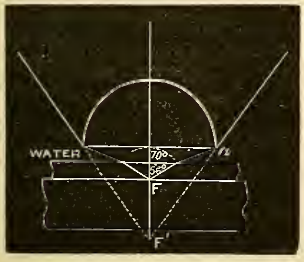
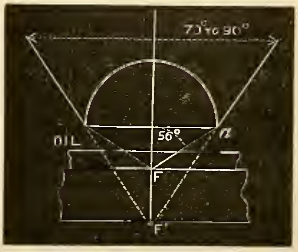


Fig. 21.



(Fig. 20), there would be a cone of rays extending up to 70° on both sides of the axis, *and this large cone would be submitted to spherical aberration at the front surface a;* with glycerine this would be similar, though in less degree.

But if there is homogeneous immersion (Fig. 21), the whole cone of 112° angular aperture is admitted to the front lens without any aberration, because there is *no refraction* at the plane surface. And as the *spherical* surface of the front lens, though it may effect a considerable refraction, is without notable *spherical aberration*, the incident pencil likewise is brought from the focus F to the conjugate focus F′, and contracted to an angle of divergence of 70–90° without having undergone any spherical aberration at all.

Thus the problem of correcting a very wide-angled objective is reduced *by the homogeneous-immersion method, both in theory and in practice, to the problem of correcting an objective of moderate air angle.*

On this principle, by which the Amici type of construction is brought to its full efficiency, is based the optical advantage of the homogeneous-immersion method: i.e. the advance of defining power *per se* which is due to the exclusion of disproportionate aberration, and the increase of aperture which is *reconcilable* with perfect definition without needing any reduction of working distance apart from the requirements of technical work in high-power systems."

'The Northern Microscopist.' *—We are pleased to see the first number of a new Microscopical Journal under this title, edited by Mr. George E. Davis, a Fellow of the Society. It is hoped that its establishment "will be a bond of union between workers in the North, and that it will bring to the fore many men whose researches have scarcely been heard of, on account of their distance from the great microscopical centres;" and amongst its aims is the keeping of a record of the proceedings of the chief Microscopical Societies in the North, and so furnishing each individual member with at least as much permanent information as he would obtain if the Society to which he belonged published its own transactions—possibly more.

β. Collecting, Mounting, and Examining Objects.

Dr. Maddox's modified Aeroconiscope.—The modified form of Dr. Maddox's "Aeroconiscope," exhibited by him at the ordinary meeting of the Society on the 10th November, is figured in the accompanying woodcut.† It can be used as a vane, like the one employed in the experiments recorded in the 'Monthly Microscopical Journal' for 1870 (where the original form is figured), or with an aspirator, which can be driven by any means selected to draw a current of air through the instrument.

It consists essentially of an apparatus to collect the atmospheric dust, &c., and deliver it upon a slightly glutinous surface. In this case a glass tube *b*, and a funnel *a*, which supports a platinum wire bent as shown in the figure, to hold a thin microscope cover-glass, and at the opposite end to the funnel a pair of wings, attached to a split ring, which slides on *b*, the whole supported, as seen in Fig. 22, on a conically pointed steel pin. This pin can be screwed into a reversible clamping screw, to fix on the edge of a table, chair, or window-ledge, or slips into a socket on the side of the upper vessel of the aspirator, as at *d*. The glass tube of the vane, if used fixed, is attached by a short piece of indiarubber tubing, by which the air, after depositing the dust, escapes into the upper vessel previously filled with water, and allowed to empty itself into the lower vessel, thus creating a slight current through the apparatus. If used as a vane for the wind to blow through, of course it would be necessary to detach the indiarubber tubing, and allow the vane to gyrate upon the conical pin, fixed, if

* 'The Northern Microscopist,' vol. i. No. 1. January. 24 pp. 1 plate and 2 figs. (8vo. London and Manchester, 1881.) 6*d*.

† See 'British Medical Journal,' Nov. 20, 1880.

preferred, on an ordinary triangle camera-stand. The funnel *a* should have a shorter stem than as figured, which was drawn to avoid confusion in the figure; and to still further simplify it and get rid of some of the weight, it can be made to fit the neck of the tube *b*, as a stopper fits a bottle. This is believed to be the preferable way, whether the funnel be of glass or sheet-metal, and in this case the platinum wire support *c*, can be fixed by a small adjustable clamping ring, to the tube which passes through the brass cap at the opposite end of *b*. The wings can also be made to fix on this cap, and

FIG. 22.

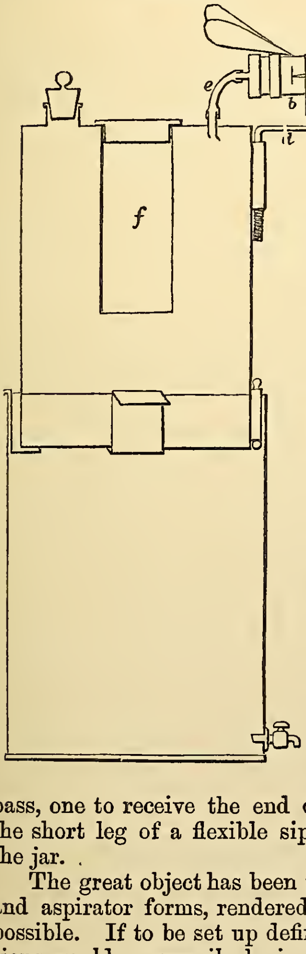
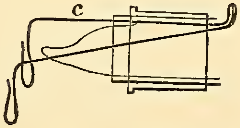


FIG. 23.



thus still further reduce the weight by getting rid of the split ring, to which they were fastened in the form exhibited and here figured. The apparatus after removal of the wings drops into the closed chamber *f*, for convenience of carriage, and the upper vessel, of a known capacity, fits into the lower one, after removing the supports by which it is held in place when in use. The top vessel is filled through the stoppered neck, whilst the water is allowed to escape into the lower vessel through an aperture near to the bottom, which can be closed by a solid indiarubber plug, *vide* Fig. 22. These vessels may be made of any convenient size, or the lower vessel, or indeed both vessels, can be got rid of, and the vane, supported by the clamping-screw to a table, can be connected to a large jar full of water, placed on a chair, closed with a tight-fitting cork, through which two tubes pass, one to receive the end of the indiarubber tube, and the other the short leg of a flexible siphon, reaching inside to the bottom of the jar.

The great object has been to combine in one instrument the vane and aspirator forms, rendered as portable and of as little cost as possible. If to be set up definitely at any particular spot, the dimensions would necessarily be increased, and some form of aspirator used that would draw regularly a measured quantity of air through the apparatus in a given time, as twenty-four hours, more or less. This would increase the complexity and expense, though doubtless it would furnish more important data than the present portable form.

Glycerine or glucose, singly or united, can be used to smear the centre of the thin glass cover opposite the nozzle of the funnel, if intended for direct microscopical examination ; but if for cultivating the entrapped germs, some other medium, containing animal matter in a sterilized solution, with a little acetate of potash, can be employed, and the cover placed on a cultivating slide or in a cultivating chamber; or, removing the thin cover-glass, the air can be drawn in direct into a sterilized medium interposed between the nozzle of the funnel and the aspirator.*

Herpell's Method of Preparing Fungi for the Herbarium.†—The editor of the 'Collection of Prepared Hymenomycetous Fungi,' publishes the method employed by him in his excellent preparations, commencing with some advice as to the collection of Hymenomycetes, with the special view of bringing home the fungi uninjured and in a condition for preparation.

The process itself is as follows :—Some finely cut gelatine is first dissolved in five parts of boiling water, and the solution daubed as thick as possible on some leaves of stiff writing-paper. One of these leaves of gelatinized paper is then moistened on the clean side and laid on a flat moistened plate. The sections of the fungi are then prepared, viz. a vertical section through the centre of the entire fungus, and superficial sections of the pileus and stipes, taken so as to cut away as much as possible of the flesh. These sections are laid on the gelatinized paper, and then pressed under a weight of 25 kilo. between white blotting-paper. After twenty-four or forty-eight hours they are regularly turned over for from two to four days; the sections are then dry, and can be cut out and fixed with gum.

The "spore-preparations" are obtained in the following way:—Immediately after the fungus is collected, the pileus is laid with its under side on paper; white writing-paper being used for all the Hymenomycetes with coloured spores; blue sized-paper for the Russulæ, Lactarii, and Cantharelli with white spores; blue English cardboard for all the other white-spored fungi. These papers require no further previous preparation; the fixing of the spores after they have fallen takes place subsequently. The spores which have been received on the writing and on the blue sized-paper are fixed by a solution of two parts mastic, one part sandarac, and two parts Canada balsam in thirty parts alcohol of at least 95 per cent. A small quantity of this lac is poured on to a flat plate, and the preparation of spores laid upon it so that they are not moistened on the upper side. The lac penetrates the paper and the spores, which are thus firmly fixed to it, the time occupied varying greatly with different kinds of spores. Those upon the blue cardboard

* A further note by Dr. Maddox on M. Miquel's remarks on his Aeroconiscope—see this Journal, iii. (1880) p. 1032—is unavoidably held over.

† Herpell, G., 'Das Präpariren u. Einlegen der Hutpilze für das Herbarium.' (8vo. St. Goar, 1880.) See Bot. Centralbl., i. (1880) p. 1279.

are, on the other hand, fixed by a solution of gelatine, to which some alcohol is eventually added, in order to assist the spores in penetrating it. The relative value of the different processes for any particular species must, however, frequently be determined by actual experiment.

Simple and Speedy Method of Staining Animal and Vegetable Sections.*—After cutting the sections, wash them in water, and allow them to soak for a while.

Transfer them to a solution of anilin violet in commercial acetic acid, the solution to be of the following composition:—

Anilin violet	1 part.
Acetic acid	300 parts.

The sections are to be left in the solution until sufficiently stained, which may be determined by removing them from the solution to clean water. If sufficiently blue, they are then ready to be mounted. If not sufficiently coloured, return to the solution.

The sections are mounted, after staining, by transferring them to a clean glass slide, draining off any excess of fluid, and adding a drop of solution of acetate of potash of the following strength:—

Acetate of potash	1 oz.
Water	½ oz.

Cover, and fasten the cover with varnish, permanently if wished. The advantages of this method are its simplicity and the beauty of the results attained; the disadvantages are that the specimens may fade within a year or two.

This method is taken from Orth's recent work on histology, and is one strongly recommended for demonstrating the structure of cartilage.

Staining and Mounting Pollen.†—At a recent meeting of the New York Microscopical Society, some slides of stained pollen were exhibited (the preparation of the Rev. J. T. Brownell), which are said to have been of special excellence.

The process of preparation was as follows:—A small quantity of pollen having been placed on the centre of the slide, a small drop of staining fluid (anilin dissolved in alcohol) is placed upon it. Then wash by dropping on pure alcohol until all traces of sediment or of stains upon the glass among the pollen grains are washed away. Wipe clean with a dry cloth drawn over the end of a pointed stick, turning the slide rapidly on the turntable. When thus cleaned and quite dry, put on a drop of spirit of turpentine, and then the balsam and cover.

A few kinds of pollen are distorted by the action of alcohol. Some of these can be stained by the use of an ammoniated solution of anilin. Those that will not bear this solution may be mounted unstained.

* Amer. Mon. Micr. Journ., i. (1880) p. 143.
† Ibid., p. 206.

Dry Mounts for the Microscope.—Mr. A. W. Waters sends us the following remarks suggested by the note on Professor Hamilton Smith's paper in the last number of the Journal: *—

Having mounted several thousand specimens of Bryozoa and other objects in dry mounts, it seems advisable to put the experience thus gained on record, even though there is no claim to any new observation or any important fact observed. Unfortunately it has been necessary to remove a large number of them several times, and in consequence they have been subjected to the severest test of durability, for probably anything which stands the carelessness of Italian railway porters may be considered durable.

All are mounted on glass slips, as this enables both sides of an object to be examined, and they are protected from dust by the cover. Wood slips, which are used by many collectors, are found too liable to warp when old, and the objects are thus damaged or broken. This can be seen in some of the valuable slides in the British Museum. With small cells there are few difficulties, but with deep cells there is great danger of springing, and we may safely conclude that those which after being made a few years stand railway journeys the best may be considered the most durable and most suitable for museum specimens, so as to be available for reference in 50 or 100 years. Some of the specimens referred to are large colonies mounted in glass "built" cells, some as much as half an inch deep, mostly fastened on with gold size, which should be rather thicker than that used for attaching the cover, and with these cases of springing in consequence of percussion have been very few, and these few cases have been the result of special circumstances; on the other hand, with some made with zinc varnish, several cases occurred, and the experience thus gained proves that zinc varnish soon becomes too brittle. Trial has been made of large zinc and other metal rings which have been carefully roughened with the file, but the results have been so unsatisfactory that all metal rings are now discarded as being the most liable to leave the slide. Ebonite rings have stood well, but indiarubber rings about $\frac{3}{4}$ inch in diameter have given the best results, but these are not available for deep mounts, as they are not made much thicker than $\frac{1}{8}$ of an inch. For still smaller things paper and card rings, which can be bought for the purpose, for a very small sum, have been employed, and in all these cases it is advisable to keep a moderate stock on hand, of various sizes, as thus the varnish or cement has time to dry, and there is less danger of the object becoming attached at the side, if left free; but, where it can be done, it is well to attach the object with a spot of cement in the centre of the cell.

Some shellac rings, similar to those mentioned by Mr. Smith,† have been used for some years, but experience has shown that it is well to run gold size round these after they have been mounted and cooled, as otherwise they become too brittle; but with these rings, which are attached by melting the shellac covering the ring, there is however a danger of small crystals forming inside, caused by the vaporization of the shellac when heated.

* See this Journal, iii. (1880) p. 1038. † Ibid., p. 1039.

Recently some rings have been attached with liquid marine glue, and the results so far seem very satisfactory; but as the experience of them does not go far back, no sufficient opinion as to their durability can be expressed.

As a precaution, the indiarubber rings have not been used too new, and have in most cases been attached to the glass and in stock some time before the object was mounted; this, it was thought, would minimize the danger of sulphur being deposited on the glass and object; and those mounted several years ago all remain perfectly clear.

Carbolic Acid in Mounting.*—Mr. C. M. Vorce finds that an object which has been macerated in potash can be mounted in balsam without drying, by the following procedure:—Take the object from the potash solution, and arrange it on a glass slip, for which purpose a piece of window-glass, 2 in. square, is very convenient. If necessary, wash it with pure water, using a camel's-hair pencil; then drain away the water, and wipe around the object, add strong potash solution, and after it has been in contact with every part of the object for a few minutes, drain it away, and again wipe the glass as close around the object as practicable. Add carbolic acid (pure) in considerable excess, and warm the slip gently; this causes the object to become opaque, but do not be disconcerted by this. After a time, say fifteen minutes for a small thin object, warm the slip and pour off the acid, and again wipe. Add more clear acid, and transfer the object to a mounting-slip, which is easily done without injuring the object as follows:—Lay the slip on a box or block of about its own width, and ½ inch or more in height, pour the acid from the square slip on to the middle of the mounting-slip, and reversing the square slip, bring it down upon the drop of acid so that the object may first touch it, when, with a little care, the object will settle down into the acid without being much, if at all disarranged. If necessary, it is then arranged under the dissecting Microscope, and when brought into the desired position, if it is clear and quite transparent the acid is drained away, balsam added, and the mount completed.

If found to require cleaning, it can be done with needles and a brush, as in ordinary cases. If clean but not transparent, warm and set away under a bell-glass until it is fit to mount, making another change of acid if necessary. In all cases it is best to take the last change of acid from a bottle kept specially clean and pure for that purpose. Objects macerated in acetic acid can be treated in the same way.

Wax Cells.†—The same writer says, that so much has been lately said about wax cells, a little more cannot be amiss. He has some that are utterly destroyed, and more that are very much injured by the deposit on the under side of the cover. The worst of these were mounted by one who was given to using turpentine to soften the wax; this is probably the cause of the deposit in these slides. His own

* Amer. Mon. Micr. Journ., i. (1880) p. 207.

† Ibid., p. 208.

mountings are very free from this trouble, though all made with wax-bottomed and asphalt-covered cells. The reason of this, he thinks, is that the cells are mostly made a long time before they are used; his business being such that he can only devote time to microscopy in the mornings and evenings. Hence most of the work is interrupted by twelve-hour intervals. To save time, a lot of cells are made up at once, using double-thick pond-lily wax and brass curtain rings, sometimes a little flattened.

To make the cell, place the ring on the wax and press it down with a slip; then with a wet penknife-blade, cut around the ring outside, and lift it out. The disk of wax is then punctured from below with a needle in two or three places near the middle, and if not already raised a little in the centre, it is gently bent with the finger, so that when placed on the slide it will touch only at the edges. The ring is now placed on the centre of a slip in the turntable, and gently pressed to make it adhere. Then removing the slide, it is held over a lamp, keeping it level; the wax first softens at the ring, and as the softening proceeds towards the centre, the air escapes through the needle-holes, and blisters are prevented as the wax settles down upon the slide. Before the wax actually melts, the slide should be removed, and returned to the turntable to see if it is still centered. If the wax does melt, no harm is done unless the ring slides from its place before it cools. When cool the ring is firmly fixed, and it is then coated on the turntable with Brunswick black, though perhaps shellac would be safer from liability to the "sweating." Having prepared from four to six dozen cells of different sizes, they are laid away in drawers, and after a time, three days to three weeks, as the case may be, the cells are coated again. And when this second coat is dry, any time after a week, the cells are fit for use. In mounting he uses nothing to fasten the object to the wax, but presses it down with a needle or shaved splint of whalebone, or the finger-end in many cases. Objects in fluid are to be allowed to evaporate in the cell, leaving them covered from one night to a day or two, as may be. When the cells are covered, covers are used cut by the author's cover-cutter, just large enough to rest inside the brass rings without falling through. Then the angle between the edge of cover and top of the cell is filled up with wax by means of a pointed knife-blade, using the wax as putty is used on a window. The mounts can now be left for finishing till a leisure time, but it is desirable to apply a light coat of cement before putting them away, and at any time afterward when time can be found he goes over them again, and usually a third time before finishing.

Simple Device for Handling Thin Covers.—Mr. J. C. Douglas writes, that he has long wanted a simple appliance for picking covers out of the liquid in which they may be soaking, selecting them from their box, placing them flat upon the object to be examined or mounted, and picking them off the slide when necessary after examining the object covered. Forceps and needles have grave inconveniences. Chase's mounting forceps * simply drop on the

* See this Journal, iii. (1880) p. 508.

cover, and are inferior both in simplicity and utility to the following plan.

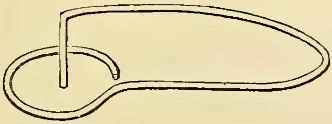
Cut a piece of suitable size from a flat rubber ring, fix this, by a large-headed pin cut short, on to the end of a cedar-stick, driving the head of the pin so as to form a depression in the rubber, wet the rubber, and on pressing it on a cover-glass it will adhere to it, and the glass may be manipulated as desired. To disconnect the rubber from the glass, it is merely necessary to incline the stick so as to detach the rubber at one edge, when the adhesion ceases at once. The apparatus is more durable if a little cementing material be used on the stick, as the pin sometimes draws through the rubber.

A cover can be readily placed flat on a slide, and picked up again if necessary, and when examining objects in fluid, the cover-glass can be put on and taken off very readily. In most cases the necessity for tilting the cover is avoided.

Mounting Clip.—In using the ordinary clips Mr. J. C. Douglas says that he has experienced great inconvenience from the difficulty of moving the slide rouud while in the clip to apply varnish to the whole circumference of the cover-glass, and the ordinary clips mostly hide the object so that it cannot be properly examined during the process of mounting. Mr. Woodward's device* has the disadvantage of keeping the slide on the turntable until the varnish sets, so that the turntable cannot be used for a number of slides in succession.

Mr. Douglas takes a piece of stout brass wire and bends it into the shape shown in Fig. 24. The ring is as large as the largest cover-

Fig. 24.



glass, so that it does not obscure the object; the pressure is readily regulated by bending the wire, and the point of the wire comes in the centre of the ring. The length of the clip is such as to admit of the slide, held between the end of the wire and the ring, revolving round the end of the wire. The end of the wire is rounded.

The mode of using the clip is as follows:—The cover-glass being in position, and gently pressed down, the slide is placed in the clip, in which it can be washed, examined, the edge of the cover-glass varnished, &c.; the holding coats of varnish are put on by hand, revolving the slide in the clip as necessary.

Arranging Diatoms, &c.†—The arrangement of small microscopic objects, such as diatoms, Foraminifera, &c., on slides in regular

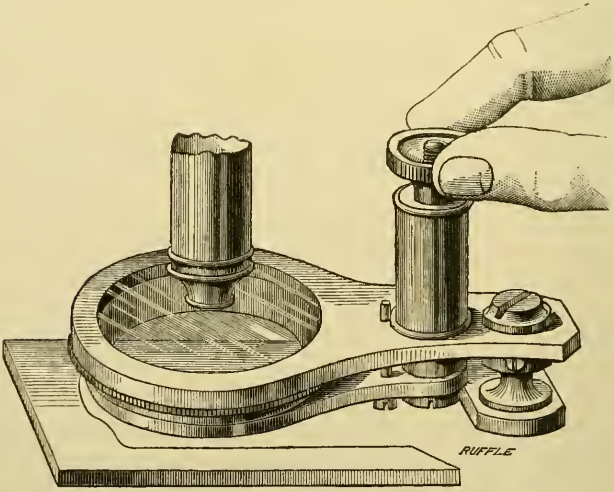
* See this Journal, iii. (1880) p. 507.
† Mr. J. Deby, in Journ. Quek. Micr. Club, vi. (1880) p. 166.

lines, circles, or patterns, can be facilitated in the following way:— Draw with a pen and ink cross lines, or circles, or any other figure required, on the surface of the plane mirror of the Microscope, then focus down until the image of these lines is seen on the upper surface of the top lens of the condenser. By means of a mechanical finger, or of a steady hand with a rest, no difficulty will be experienced in placing the objects in perfectly regular order.

Holman's Compressorium and Moist Chamber.—Mr. D. S. Holman's new compressor is shown in Fig. 25. The following description is transcribed verbatim from the original:*—

"This apparatus differs from all other compressors in being so arranged that the mica cover is fixed and immovable, while the lower thicker plate of glass is moved up and down by means of a screw nut and spiral spring, an arrangement which enables the student to adjust the apparatus so as to apply with certainty any degree of pressure

Fig. 25.



upon any soft object without risk of breaking large and expensive cover-glasses, crushing the object unexpectedly, or injuring high-power lenses. The writer by its means was enabled to study with great deliberation and certainty the internal anatomy of the larva of the plumed crane-fly (*Corethra plumicornis*). In this case the pressure could be so nicely adjusted as not to disturb in the slightest degree the normal physiological actions of the larval fly; the physiological action of the heart could be readily studied, as well as the significance

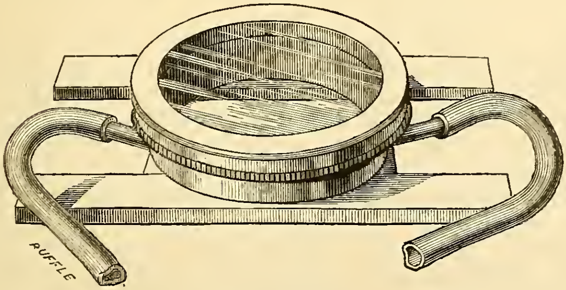
* John A. Ryder, in the 'Journal of the Franklin Institute,' 1880.

of the so-called apolar ganglion-cells of that organ appreciated. Every life-process, in short, was visible through the transparent body of the creature, so that if well studied by the help of this apparatus, the student will have acquired a mental image or epitome of the morphology and physiology of that great group of jointed animals, the Articulates of the naturalist.

Equally good results were got by its use in studying the embryology of the shad, where it revealed to the writer, and for the first time to science, the presence of a so-called polar vesicle in the earliest stages of development.

In Fig. 26 we have a combination of the familiar animalcule cage and the siphon slide, also designed by Mr. Holman. The edge

Fig. 26.



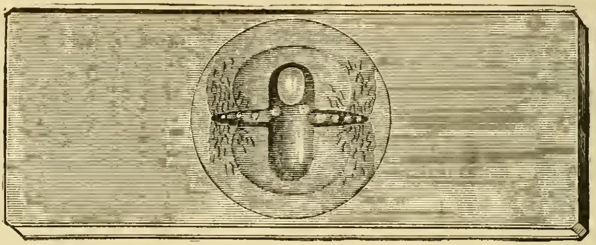
of the cover or cap is bevelled, so that by rotating it against the inflow and outflow tubes of the siphon arrangement, a very convenient and effective compressor is obtained. The apparatus is equally as valuable as the compressor before described, because of the certainty with which one can gauge the amount of pressure which is applied; also on account of the facility with which water may be renewed in it when used as a "moist chamber" for studying growing fungi, without in the slightest degree disturbing these delicate plants. The value of the apparatus is further enhanced by the facility with which it may be used as a siphon-slide for keeping aquatic larvæ, worms, &c., alive for a lengthened period for study or exhibition. It is equally useful as a dry compressor for holding, studying, and drawing minute soft-bodied insects in the living state."

Holman's "Life Slides."—Figs. 27, 28, and 29 are three "life slides," which were invented by Mr. Holman some years ago, though we do not remember that they have been figured in this country.

(1) "*Life Slide.*"—This slide (Fig. 27) consists of a 3×1 inch glass slide, with a deep oval cavity in the middle to receive the material for observation. A shallow oval is ground and polished around the deep cavity, forming a bevel. From this bevel a fine cut extends, to

furnish fresh air to the living low forms of life. They will invariably seek the bevelled edge of the cavity, and so are in the reach of the

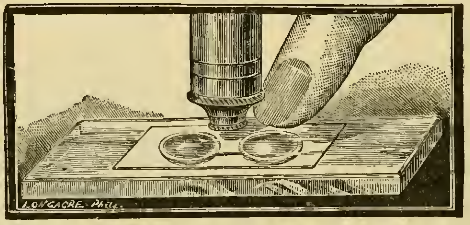
Fig. 27.



highest powers. Owing to the supply of fresh air, the living animalcule may (it is said) be kept for weeks. It is adapted, too, for studying the circulation of the blood in the tail of the tadpole.

(2) "*Life and Current Slide.*"—In a slip of plate-glass (Fig. 28), two oval cells are ground and polished, which are connected by a very shallow channel. If the cells are partly filled with blood and covered by a thin cover-glass, the expansion of the air in one cavity will drive

Fig. 28.

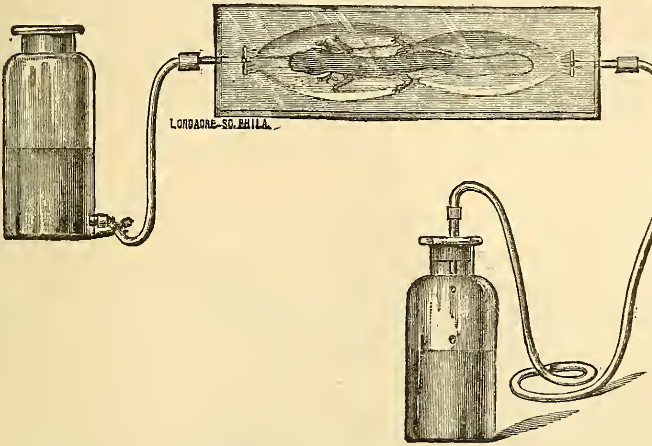


the blood through the channel, and then it may be observed under the most favourable condition, even for a high power. The apparatus is so sensitive that the current may be changed by bringing the finger near one of the cavities, and arrested by moving the finger away.

(3) "*Siphon Slide.*"—This (Fig. 29) consists of a slip of thick plate glass, with two shallow oval cavities and a deep groove in the middle, to hold a small fish or Triton, and retain it without undue pressure in a fixed position. Small metallic tubes communicate with the extremity of the deep groove. Rubber tubes are connected with these metal tubes, one of these being intended for the entrance and the other for the exit of any fluid, cold or hot. When in use it is only necessary to place the animal with some water into the groove, cover it with the glass cover, immerse one of the rubber tubes in a jar of water, and, by suction, draw the water through the apparatus. If the slide is placed on the stage of a Microscope the jars should stand lower,

so as to make the slide the highest part of the siphon, and the pressure of the atmosphere holds the cover tight.

FIG. 29.



This apparatus is adapted for the gas-microscope, as by a constant flow of cold water the Triton can be kept in the focus of the condenser for hours.

Mapping with the Micro-spectroscope.*—Mr. J. Deby says that when mapping with the micro-spectroscope the difficulty of measuring exactly the position of fine lines or absorption-bands is often great, but that he finds that in most practical cases the micro-spectrum can be thrown upon a sheet of white paper by means of an ordinary camera lucida placed over the eye-piece of the spectroscope, strong light by means of a condenser being thrown through the liquid under examination. By means of an ivory rule, finely divided, and brought back to a known line, say D, all other lines or bands may be directly measured off on the rule, and, if desired, the exact results in millionths of a millimetre may then be computed by any of the known interpolation formulæ, such as are given in Mr. Suffolk's useful little book.†

Tubes for conveying Moist Specimens, Diatomaceæ, &c., by Post.‡—J. J. M. recommends a thin membrane of gutta-percha, such as is used by surgeons, cut to the required size. The joint is made by dipping a camel-hair brush in chloroform, drawing it along the edge, say half an inch wide, and then placing the part to be joined to it before the chloroform has evaporated. If the tubes are only three parts full, it will allow of a little pressure, should it occur in transit. The cover can be made by rolling brown paper over a ruler or other suitable form, fastening with paste, as firework cases are made, allowing to dry, then cut to lengths required.

* Journ. Quek. Micr. Club, vi. (1880) pp. 165–6.
† 'Spectrum Analysis as applied to Microscopical Observation.' (8vo. London, 1873.)
‡ Sci.-Gossip, 1881, p. 17.

Glass Crystals.*—The crystal, Fig. 30, is that of ordinary window-glass, which is formed by cooling down large masses of fluid glass for several days to a temperature slightly higher than its point of viscidity. These crystals were discovered about ten years ago, and at intervals up to the present day Mr. W. D. Herman and Mr. G. E. Davis have spent much time in investigating their nature and in photographing them. Their close relationship to rock-structure make

FIG. 30.

them exceedingly interesting, as well as the large number of forms which are often found in the same square inch of glass. Some mixtures of glass give these star-crystals only, while in others there are none found save prisms; and these latter form excellent polariscope objects.

The figure was prepared by photographing the crystal with the aid of a $\frac{1}{4}$-inch objective, the collodion-film being then transferred to the wood-block.

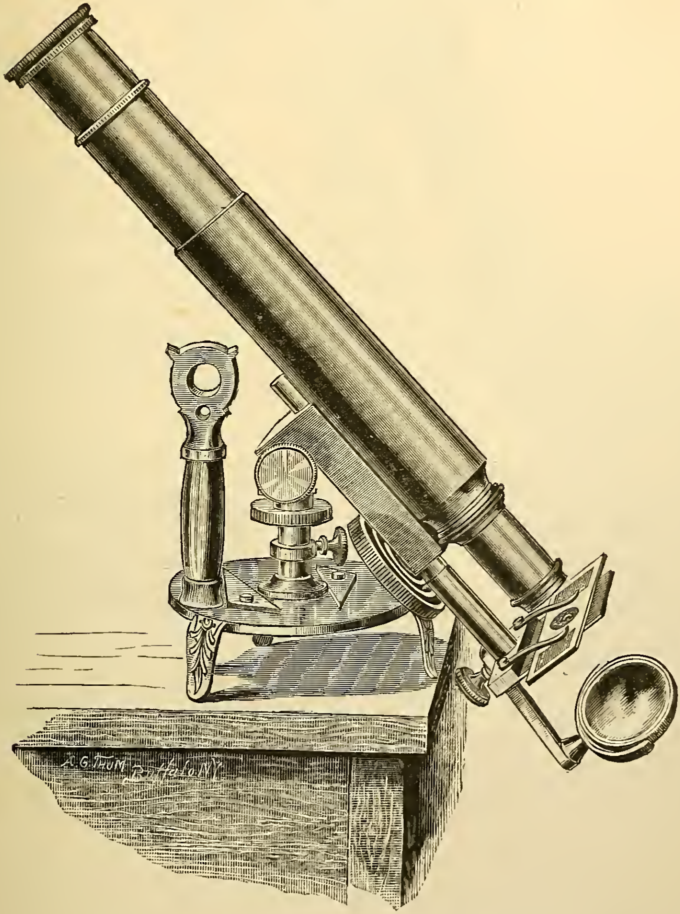
* 'Northern Microscopist,' i. (1881) pp. 21–2. 2 figs.

MICROSCOPY.

a. Instruments, Accessories, &c.

Griffith Club Microscope.—Figs. 39, 40, and 41, show a new form of portable Microscope designed by Mr. E. H. Griffith, of Fairport, N.Y., U.S.A., and designated by him the "Griffith Club Microscope." Mr. Griffith claims for the new instrument certain

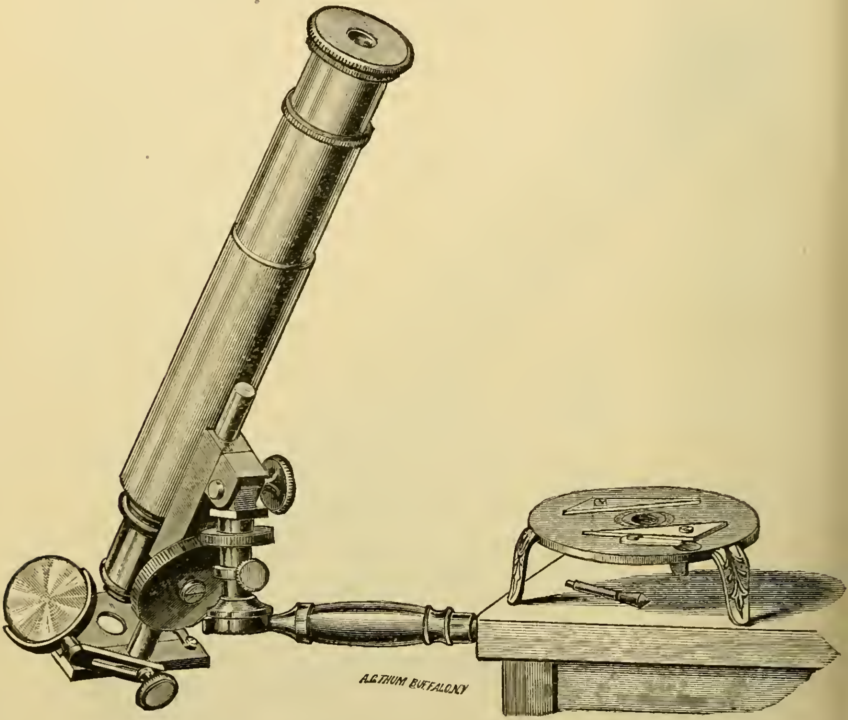
Fig. 39.



merits in regard to compactness and portability, which distinguish it specially for class or field work.

The stand proper can be attached to a metal disk provided with three feet; it then appears as in Fig. 39. The bottom of the box is also provided with a metal fitting into which the standard carrying the Microscope can be screwed, which we regard as the most convenient way of using the instrument. An extra screw-arm (shown lying in front of the box in Fig. 41) is also provided, which can be screwed to the end of a laboratory table, as shown in Fig. 40. The metal disk forming the foot in Fig. 39 also serves as an ordinary self-centering turntable, as shown in Fig. 41.

Fig. 40.

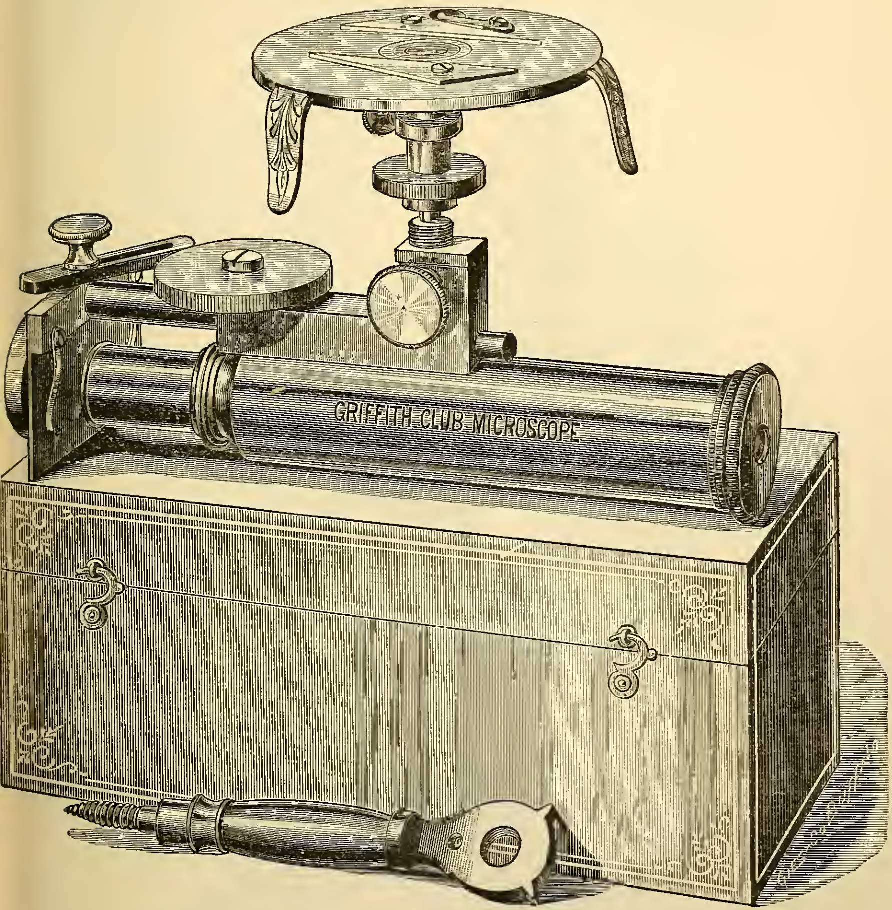


The coarse adjustment is effected by a sliding cylindrical rod attached to the back of the microscope-body. The fine adjustment consists of a large milled head attached to the lower end of the bar in which the coarse adjustment rod slides, the inner face having a deep spiral groove of nearly three turns, in which works a pin projecting behind the cylindrical tube carrying the stage; the rotation of the spiral causes the pin and tube, together with the stage, to move somewhat slowly in a vertical direction within a range of half an inch —sufficiently well for the use of low powers. (Fig. 39 shows the pin in the second ring of the spiral.)

The mirror has the usual gimbal motions, and is attached to a sliding bar at the back of the stage, swinging laterally and approximately concentric with the object upon the stage. (Fig. 40 shows the mirror swung above the stage.)

The draw-tube has the "Society" screw at the lower end, and a

FIG. 41.



fitting is provided to permit the inclination of the stand to any desired position.

The feet of the turntable can be removed for convenience of packing. The whole of the metal work is nickelized.

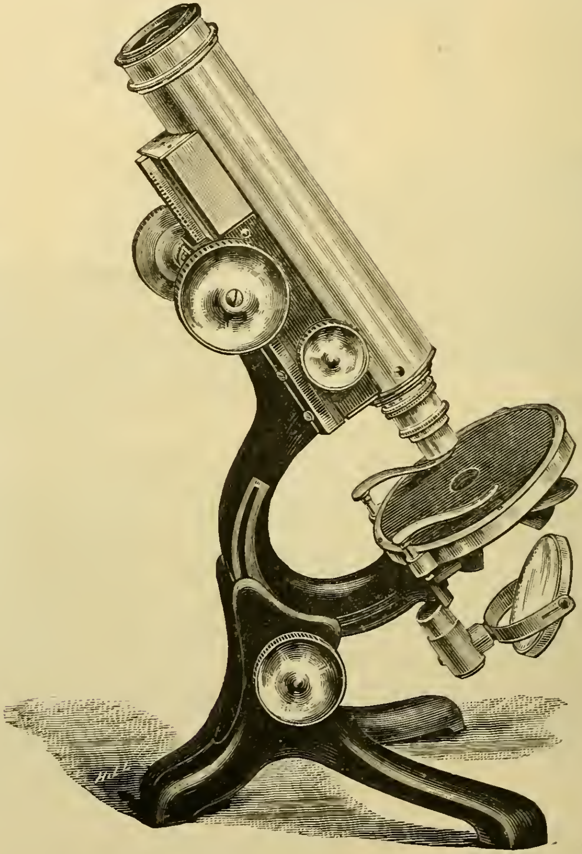
The box (shown about half-size in Fig. 41) is intended to carry the stand, eye-piece, two objectives, turntable, sundry bottles, &c., and the lid is glazed with strong plate glass. We understand that

Mr. Griffith proposes to apply an extra carrier for a small candle or other illumination for class work.

The new Microscope appears to be the result of much ingenious planning on the part of its author to produce what he terms a "*multum in parvo*" instrument.

Swift's Student's Microscope (Wale's Model).—It will be seen from Fig. 42 that the main feature in Wale's Microscope *—the inclina-

FIG. 42.



tion of the main limb by the motion in sector between vertical jaws—has been applied by Messrs. Swift in their new stand. Their calotte diaphragm is also added (shown in part beneath the stage).

The principal novelty is the fine adjustment (Fig. 43, nearly full

* This Journal, iii. (1880) p. 1046.

size). A is a brass plate having short angle-bearings at either end sliding in the grooves B B and carrying at the lower end a ring into which the objectives are screwed. A spiral spring C presses down the plate A. The focussing is by means of the fine screw worked by the milled head F, the point of which acts upon the trigger-shaped lever D (attached to the side), which pushes against the small metal disk E (mounted on A and rotating on a pinion to

Fig. 43.

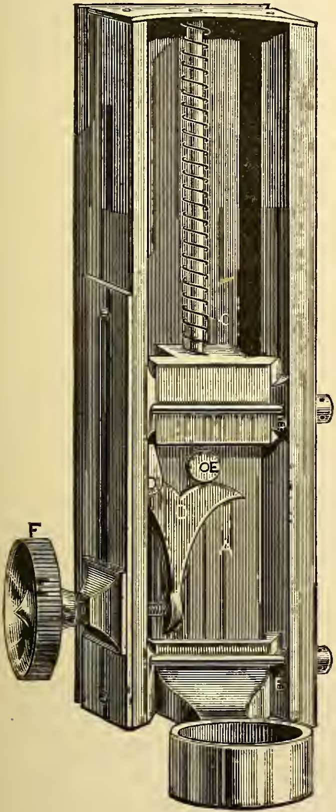
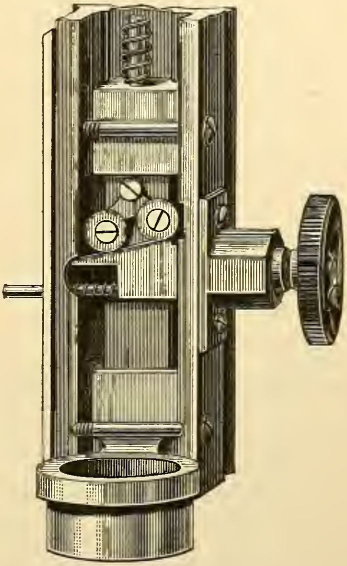


Fig. 44.

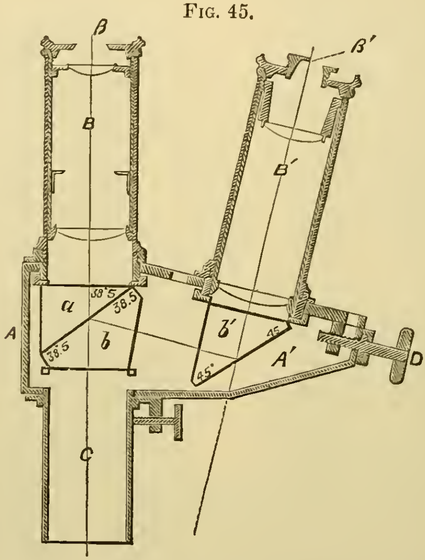


diminish friction) and this lifts up the slide A against the pressure of the spiral spring above. The ring carrying the objective is quite independent of the microscope-body, and should the slide A be found to work too easily or the reverse, the bearings can be readily adjusted by the capstan screw-heads shown at the side.

An improved application of this fine adjustment has since been devised, as shown in Fig. 44; the modification consisting of a wedge-shaped lever worked by the fine-focussing screw (against a short spiral spring) and acting on the slide A by means of the two small revolving disks attached loosely by a triangular fitting to the pinion at E. By making the slope of the wedge very acute, and the thread of the screw very fine, the focussing movement is rendered unusually delicate. This latter form of fine adjustment is designed to be applied to more expensive Microscopes.

Abbe's Stereoscopic Eye-piece.*—Fig. 45 represents this instrument in section. The body A A′ contains three prisms of crown glass, *a*, *b*, and *b*′. The two eye-pieces B B′ are let into the top plate, the former being fixed, whilst the latter has a lateral sliding movement; the bottom plate carries the tube C for inserting the eye-piece into the microscope-tube like an ordinary eye-piece.

FIG. 45.



The two prisms *a* and *b* are united so as to form a thick plate with parallel sides, their continuity, however, being broken by an exceedingly thin stratum of air—less than 0·01 mm.—inclined to the axis at an angle of 38·5°. The cone of rays from the objective is divided into two parts, one being transmitted and the other reflected. The transmitted rays pass through *a*, *b* without deviation, and form an image of the object in the axial eye-piece B. The rays reflected at the angle shown in the figure pass through the second surface of the prism *b* (upon which they are incident at right angles), and emerging at an inclination of 13° with the horizontal, are totally reflected into the eye-piece B′ at an angle of 90° by the hypothenuse surface of the right-angled equilateral prism *b*′, the axis of which also makes an angle of 13° with the axis of the Microscope.

* Zeitschr. f. Mikr., ii. (1880).

Adjustment for different distances between the eyes is effected by the screw D, which moves the eye-piece B′, together with the prism b', in a parallel direction. The tubes of the eye-pieces can also be drawn out, if greater separation is required.

The eye-pieces have the usual two lenses, but are of special construction in order to equalize the length of the direct axis and the doubly reflected axis, and in spite of this inequality obtain sharply defined images of equal amplification with the same focus.

Stereoscopic vision is obtained by *halving the cones of rays above the eye-pieces.* This is effected by stopping off half of the real image of the objective opening formed above the eye-pieces at the so-called "eye-point" β or β', which represents the common cross-section of all the pencils emerging from the eye-piece. A cap, with a semicircular diaphragm, is fitted to the eye-piece (shown in the figure over B′), the straight edge of which is exactly in the optic axis of the eye-piece, and can be raised or lowered by screwing so as to obtain a uniform bisection of the cones of rays from every point of the field.

The height of the diaphragm is regulated once for all for the same length of the microscope-tube by finding the position for which the aperture-image (which on withdrawing the eye from the eye-piece is visible as a bright circle above it) shows no parallax against the straight edge of the diaphragm, i. e. so that on moving the eye laterally the image always appears to adhere to the edge.

In addition to the above caps with diaphragms, the instrument is supplied with ordinary caps with circular apertures, as in B. They taper slightly, and simply slide into the eye-piece, so that they can be readily changed.

The special feature of the instrument is the ingenious arrangement whereby, by simply turning the caps with the diaphragms, orthoscopic or pseudoscopic effect can be produced instantaneously at pleasure. It is more particularly available for tubes of short length for which the Wenham prism is inapplicable.

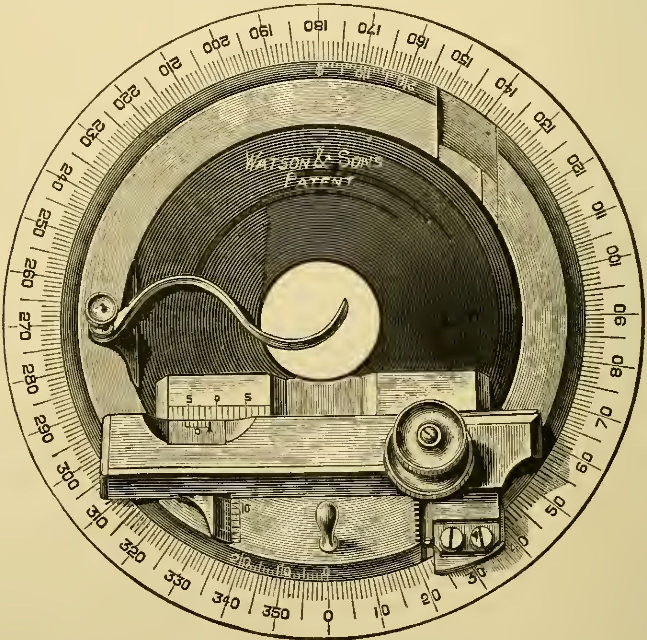
Some discussion subsequently took place as to this instrument,* in the course of which it was pointed out that the device for dividing the rays was similar to that suggested by Mr. Wenham in 1866,† the method of its application, however, and the action of the binocular as a whole being essentially distinct and in fact truly stereoscopic, and not *non*-stereoscopic as supposed.

A further point raised was ‡ that a *crossing* of the axes in such an arrangement was essential, in regard to which, however, Prof. Abbe properly points out—what has hitherto not been appreciated—that stereoscopic or pseudoscopic effect does *not* depend essentially on crossed or not-crossed axes, but upon either the outer or inner halves of the pupils of the observer's eyes being put into action in binocular vision. As the author has dealt fully with this point in the paper read at the January meeting,§ we need not refer further to it here.

* Engl. Mech., xxxii. (1880) p. 323.
† Quart. Journ. Micr. Sci., xiv. (1866) p. 104.
‡ Engl. Mech., xxxii. (1880) p. 352.
§ See this Journal, *ante*, p. 203.

Watson's Mechanical and Rotating Stage.—Fig. 46 shows an improved form of stage by Mr. Watson, with the mechanical movements applied to and wholly controlled on the surface and within the circumference. It will be remembered that at pp. 117–18 we figured and described Tolles's mechanical stage, embodying similar movements. In the Watson stage, however, the lower plate or bar, travelling vertically, is sunk below the surface of the stage and moves in a dovetailed groove ploughed out of the rotating plate, and carries a pinion whose teeth gear into a rack cut into or attached to one side of this

Fig. 46.



groove. By turning the milled head fixed to this pinion—the upper one in the figure—the plate carrying it moves in a vertical direction. To this bar is attached another at right angles, with a similar groove ploughed out, in which works a second plate having teeth cut upon its lower edge gearing into those of a second (hollow) pinion placed on the first, and, by means of a tube fitting the axis of the latter, turning independently upon it by the lower milled head shown. Thus, as with the ordinary "Tyrrell" pinion movement, by turning either of the milled heads separately, rectangular motion can be obtained—or, by turning them both together, diagonal motion.

To the plate or bar, traversing horizontally, is attached the top plate (upon which the object slide is placed), the thickness of which is about the fiftieth of an inch. The pinions are made to work on the same axis for convenience of being controlled by one hand.

The top plate has an improved spring arrangement (largely adopted in America), for securing the slide; upon unscrewing the milled head on the left hand, the spring may either be turned aside or removed altogether, when the stage will be free to carry a trough or other large object.

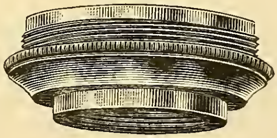
The usual graduated "finders" are added, but instead of the ordinary pointers, verniers, reading to $\frac{1}{100}$ of an inch, are applied.

The circular stage rotates within a broad fixed ring. This ring is preferably made of phosphor-bronze, and is graduated round the whole circle, and the readings are taken by verniers. For petrological or other purposes requiring exact angular measurements, the verniers will be found of service. In the stage figured the range of the rectangular motions has been limited to an inch in either direction, but when requisite this can be largely increased.

The total thickness of the stage is only about $\frac{1}{4}$ inch. Actual use is necessary to determine whether the endeavour to get extreme thinness has or has not been carried too far so as to give liability to flexure.

"Butterfield" Gauge of Screw for Objectives.—Frequent references have recently been made in the American journals to a gauge of screw for objectives of much larger diameter than that of the "Society" screw. It is known as the "Butterfield" gauge, and is shown in Fig. 47 (actual size) in the form of an adapter to screw directly into the microscope-tube; the opening beneath is of the usual "Society" gauge. The purpose of the new gauge is to permit the extension of the apertures of low powers by the utilization of much larger diameters of back lenses than can be utilized with the smaller gauge—the latter would, in fact, act as a diaphragm to the new objectives, cutting off a portion of the effective aperture.

FIG. 47.



Homogeneous-immersion Objective with extra Front Lenses.—Messrs. Powell and Lealand have completed a $\frac{1}{12}$ having two extra front lenses on the plan noted in vol. iii. p. 1050. The maximum numerical aperture is 1·43 (= 140° in crown glass of mean index 1·525), obtained by a front lens several degrees greater than a hemisphere, mounted on a plate of glass ·003 inch in thickness, which is itself mounted in the usual metal-work by the zone projecting beyond the circumference of the lens.

With this front lens the focal distance from the exposed face of the plate on which the lens is mounted is ·007 inch.

A second front, nearly a hemisphere, is mounted in the usual way by a burred edge of metal covering the extreme margin of the lens. This front gives a numerical aperture of 1·28 (= 115° in glass), and the focal distance is then ·016 inch.

The third front provides a numerical aperture of 1·0 (= 82° in glass, as nearly as possible), and the working distance is then ·024 inch —probably the greatest working distance hitherto obtained with a $\frac{1}{12}$ of that aperture, a result of course due to the homogeneous-immersion formula.

The new objective thus affords an important practical demonstration of the accuracy of the views enunciated by Professor G. G. Stokes, in his paper in vol. i. pp. 140-1, that if a front lens, aplanatic *per se*, were constructed of very large aperture, by reducing the thickness of the lens zones of the aperture would also be cut off, and the distance gained between the spherical refracting surface and the focus would be available for "working" distance. The three fronts exemplify this exactly, for they are all made from the same substance of glass and the curvatures have the same radius, the interchange of fronts simply changes the aperture and the working distance, the magnifying power being the same with each (allowance made for the impossibility of mounting the fronts, so that the vertices of the curved surfaces should be *exactly* at the same plane—that is, at the *same* distance from the posterior combinations). The utilized diameter of the posterior lens (with the front of highest aperture) is the largest that has been hitherto utilized for a $\frac{1}{12}$; the second front utilizes a less diameter, and the third still less,—the ratios being that the front of lowest aperture utilizes a diameter expressed by the numerical aperture 1·0, the second one 1·28, and the highest 1·43, which can be actually verified by the help of an auxiliary Microscope.

Murray and Heath's Polarizing Apparatus.—Mr. R. C. Murray has devised a plan of applying the analyzing Nicol in a sliding-box fitting, to be attached to the microscope-tube *as a nose-piece*, by which means the prism can be readily shifted in or out of the field for examining rock-sections, &c., by ordinary or polarized light.

Fig. 48.

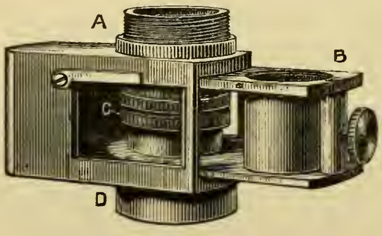


Fig. 49.

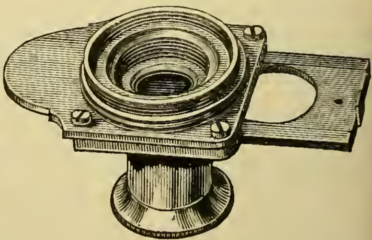


Fig. 48 shows the device ($\frac{2}{3}$ size); A is the "Society" screw for attachment to the tube, while the objective is screwed into D; B is the sliding-box, the tube C carrying the Nicol's prism, that can be rotated by the double-milled edge shown. When the analyzer is not required it can be pushed "home" in the box, and the other tube then leaves the axis of the Microscope free. A spring at the side slightly keys the sliding-box in the two positions required, that is, either using the Nicol or not. The polarizing prism (Fig. 49) is mounted in a somewhat similar manner for use beneath the stage, the milled edge below giving the rotation.

Notes on Aperture, Microscopical Vision, and the Value of wide-angled Immersion Objectives.*

I. The Aperture Theories.—Apertures exceeding 180° angular in air.—The true notation for Aperture.

1. *The two Theories of Aperture.*
2. *"Dry" and "Immersion" Objectives.*
3. *Definition of "Aperture."*
4. *Increase of Aperture with the increase in the density of the Medium. —Apertures exceeding* 180° *angular in air.*
5. *The Photometrical Test.—Supposed Identity of the Hemispheres in different Media.*
6. *The "Resolution" Test.*
7. *The "Angular Grip."*
8. *Numerical Aperture.*

II. Angular-Aperture Fallacies.

1. *The Hemisphere Puzzles.*
   (a) *The Convex Hemisphere.*
   (b) *The Concave Hemisphere.*
   (c) *The Hemisphere as a Condenser.*
2. *Illumination Fallacies.*
3. *Power of the Plane Surface of a Lens.*
4. *The Diagram Fallacy. (The Stokes immersion and the Shadbolt dry Objectives.)*
5. *Fallacies in Practical Construction.*
6. *"Not Image-forming Rays."*
7. *"Only a Question of Nomenclature."*

III. Photometrical Questions connected with Aperture.

1. *Difference of Radiation in the same Medium.*
2. *Increase of Radiation in Glass, Oil, &c.*

IV. Microscopical Vision and the Delineating Power of Objectives.

1. *The Abbe Theory of Microscopical Vision.*
2. *The Delineating Power of Objectives and Aperture.*

V. The Value of wide-angled Immersion Objectives.

I. The Aperture Theories.—Apertures exceeding 180° angular in air.—The true notation for Aperture.

During the recent discussion on Aperture many of the old fallacies reappeared, with which we propose therefore to deal in the following notes. It should, however, be distinctly understood that we do so from a wholly impersonal point of view. So far from it being our intention to reflect upon those who gave expression to the views referred to, we recognize that they have in fact thereby done a very useful service, as it has enabled explanations to be given which will serve to prevent any such difficulties disturbing the minds of future generations of microscopists.

* Taken as read 9th February, 1881. See p. 365.

There are now so many of the Fellows who recognize the errors of the angular aperture view, that we are almost afraid they will be disposed to grudge the space given to these notes. We are, however, obliged to look at the matter a little from our own side of the table. So far as we are aware, there does not exist in print any attempt to deal in a connected form with the old theory of aperture, or to point out how it is opposed not merely to optical laws which may be considered to be more or less abstruse, but to those simpler principles which lie at the very threshold of any understanding of the Microscope as an optical instrument. Moreover, the true view of the aperture question (first propounded by Professor Abbe) has been disseminated amongst the Fellows almost entirely by verbal or written communications; and as it is to our lot, as a rule, that it falls to reply by word of mouth or by correspondence to requests for explanations, it will be a great advantage to us, and of corresponding benefit to the Society, that we should be able to refer inquirers to printed statements in the Journal, whereby much time and labour will in future be saved which can be devoted to other matters.

It will also serve to show what are the points that must be met in any attempts to prove the validity of the "angular" theory of aperture; whilst so far as regards angular aperturists, they can but rejoice on the principle of the invocation, "Oh that mine adversary had written a book!"

(1) **The two Theories of Aperture.**—There have been two conflicting theories of aperture, the one known as the *Angular* theory (which formerly had prominent supporters and was recently revived by Mr. Shadbolt *), and the other the *Numerical* (or Abbe †) theory.

The essential feature of the former theory is that it regards the *angle* only of the radiant pencil, and claims that not only may two apertures be correctly compared by the angles in the case of the same medium, but also when the media are different. An angle of 180° in air is considered to represent therefore a large excess of aperture in comparison with only 96° in water or 82° in oil (or balsam), denoting in reality the *maximum* aperture of any kind of objective, which cannot consequently be exceeded, but only equalled, by 180° in water or oil.

* See this Journal, iii. (1880) pp. 1089–92, and i. (1881) pp. 150 and 154–72, where a full exposition will be found of the old view of aperture and of the action of immersion objectives. See also Engl. Mech., xxxii. (1880) p. 115.

† This theory is known as the "Abbe" theory of aperture, from its having been first promulgated (some years since) by Dr. E. Abbe, one of the professors at the University of Jena, and an Honorary Fellow of the Society—the first living authority on microscopical optics. We are glad to acknowledge our great indebtedness to him not only for the first exposition of the erroneous view so long held by microscopists on the aperture question, but also for much other instruction in optical matters of the utmost value in connection with the theory of the Microscope. Indeed, these notes may be taken to be, as it were, "lecture notes" of instruction given by him, the "lectures" not, however, having been oral, but contained in a somewhat voluminous correspondence with ourselves and others extending over several years.

That, in fact, a radiant pencil has exactly the *same* value, for equal angles, whatever the refractive index of the medium in which it may be.

The essential feature of the second theory is that it does not regard the angle only, but takes account of fundamental optical phenomena actually existing in nature, which the old theory entirely overlooked, whereby it is shown that even when the medium is the same, apertures cannot be compared by the angles only of the radiant pencils, but by their sines; whilst when the media are different, the refractive indices of those media must also be considered. An angle of 180° in air is therefore equal in aperture to one of 96° in water or 82° in oil, and represents consequently not a maximum, but much less than the aperture which is represented by the same angular extension in water or oil.

A radiant pencil has therefore an entirely *different* value for equal angles in media of various refractive indices.

It will be seen that the points of distinction between the two theories are by no means differences of nomenclature only,* but turn upon fundamental physical and optical principles the very existence of which is wholly denied by the "angular" theory; the point of essentially *practical* importance to the microscopist, who may require for his observations large aperture, being that, contrary to the angular view, immersion objectives *have* apertures in excess of the maximum attainable with a dry objective, that is, exceeding 180° angular in air.

The "aperture question" will ever hold a most prominent place in the history of the Microscope, representing as extraordinary a series of mistakes as were ever committed in any branch of science, and in which (down to comparatively recent times) both the leaders and the rank and file were equally involved. "Aperture" may be said to have been the "*Haschisch*" of the microscopist; when *that* has formed the subject of consideration, the simplest and oldest established optical principles have not been disregarded merely, but their very converse tacitly assumed, as if the great optical physicists of this and the previous century had never lived, or had written nothing that was worthy of consideration!

(2) "Dry" and "Immersion" Objectives.—To understand the question of aperture, it is of course necessary in the first place to have a clear idea of the essential difference between a "Dry" and an "Immersion" objective. Some misapprehension exists on this point, as we have been assured that we must be entirely wrong in asserting that a dry lens can never have as large an aperture as a wide-angled immersion objective,† for said our critic, "I can show you that if

* We deal hereafter more in detail (see II. "Angular-Aperture Fallacies," No. 7) with the notion that the difference between the two views is "only a question of nomenclature"!

† By "wide-angled immersion objective" is always meant one whose angular aperture exceeds twice the critical angle of the medium used for immersion, i. e. $> 96°$ for water and $> 82°$ for balsam or oil.

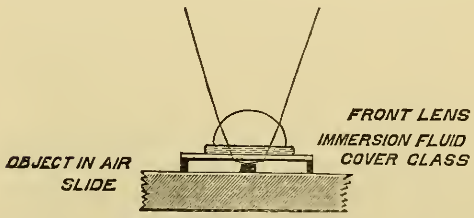
you take a dry objective and give it a different back lens, and put a drop of water or oil between the front lens and the object, it will have as large an aperture as an immersion objective"!

Dry and immersion objectives do undoubtedly differ in their construction, but the same objective may be used at one time as a true dry objective and at another as a true immersion objective without any alteration in its lenses, so that differences of construction do not constitute what logicians would call the "specific differentiation" between the two kinds of objectives. When we speak of a dry or air objective, we mean essentially an objective which is used *with a film of air intervening at some point between the object and the first surface of the objective.* (The object, therefore, being either in air or mounted in balsam or other fluid with air above.) While by an immersion objective we mean essentially one in which no film of air so intervenes, but the *whole space between the object and the first surface of the objective is occupied by a substance whose refractive index is greater than air.* (A condition which of course implies that the object itself must be immersed in fluid or closely adhering to the cover-glass.)

As the cardinal point of the angular theory is that a dry objective of 180° angular aperture (used on an object in air) represents the maximum aperture that is possible, theoretically or practically, it is desirable to appreciate at the outset that it is possible to have a dry objective of angular aperture very closely approaching 180°. When a comparison is made between a wide-angled immersion objective and a dry objective of nearly 180° angular aperture, it is objected * that no such objective can exist, for it is impossible to bring the surface of the lens in close contact with the object, or that even if we could, there "would be no working distance and no possible adjustment to suit varying sights."

But a homogeneous-immersion objective used with an object which is in air and close (but not adhering) to the cover-glass, as shown in Fig. 50, is a *dry objective*, for a film of air is interposed above the object. Further, by reason of the intervention of the immersion fluid between the front surface of the first lens and the cover-glass, *the under side of the cover-glass has become in effect the front surface of the objective*; the object may be close to this front surface, and there is of course full capability of adjustment for different sights by increasing or lessening the distance between the objective and the cover-glass. We have therefore a dry objective of angular aperture closely approximating to 180°, and with very slight spherical aberration in consequence of the exceeding

Fig. 50.



* See this Journal, iii. (1880) p. 1090.

thinness of the intervening film of air. The appreciation of the fact that it is a *dry* objective has apparently been obscured by the existence of the *immersion fluid* between the front lens and the cover-glass.

A practical advantage of having such a dry lens is that it enables us to consider the question of the surplus aperture of wide-angled immersion lenses (in excess of that of 180° angular in air) with reference to the case of *one and the same objective*, which in several ways simplifies the consideration both experimentally and otherwise. Without altering the illumination or removing the objective from the Microscope, but simply shifting a slide from that part which contains a dry object to that which has a similar object mounted in balsam, the difference in the aperture of the objective under the two conditions is at once made visible.

(3) Definition of "Aperture."—The first doubt on the mind of an angular aperturist is whether the numerical aperturist is not a person of such confused ideas, or at any rate of such neglected optical education, that it must be a waste of time even to hear what he has to say. This is a perfectly genuine doubt, because the angular aperturist hears his opponent speak of (1) an aperture in *excess* of that of 180° angular in air, and (2) of a balsam-angle of 82° being the "optical equivalent" of an air-angle of 180°, so that he assumes the numerical aperturist not to be aware, 1st, that there can be no *angular* aperture beyond 180°, and, 2nd, that a part can never be equal to a whole!

When he is satisfied that the numerical aperturist does not dispute either of these propositions, and that he lays stress upon "aperture" as opposed to "angle," his next suspicion is that some *double entendre* must lie hidden in the word "aperture."

There is no reason for objecting to the definition of the term "aperture" insisted upon by most angular aperturists, viz. as meaning not resolving-power, but essentially "*opening*." * In acting upon this definition, however, and attempting to estimate the relative "openings" of objectives, only the pencils *admitted* into the objective from the front have hitherto been considered. The alternative view is now so obvious, that it seems strange it should not have occurred to any one before Prof. Abbe—notwithstanding the number of minds that have been at work on the aperture question at various times—to regard not the admitted but the *emergent* pencils (between which he established the existence of a general relation). Whether we take the pencil which *emerges from* the objective or that which is *admitted into* the objective, is obviously the same thing as regards the present question, for no one will contend that anything can emerge that has not first been admitted. The great and obvious advantage in dealing with the emergent pencil is that it is always in air, and so the perplexities are eliminated which have enveloped the consideration of the admitted pencil, which may be in air, water, oil, or other substances of various refractive indices.

* There are some, however, who treat the idea of "opening" as of secondary importance in regard to aperture, and as giving only greater illumination, which can of course be obtained otherwise!

Aperture therefore, as meaning distinctly "opening," may be properly defined by reference to the diameter of the pencil (at its emergence from the back lens) which the objective has taken up from any given point of the object and collected to a focus at the conjugate point of the image. Not, of course, the *absolute* measure of this diameter or "opening," for that would class a 1-inch objective as of larger "aperture" than a $\frac{1}{2}$-inch, but the *relative* opening—that is, the opening in relation to power or "focal length."

Thus, if two objectives are of the *same* power, the one that has the larger opening—that is, the one which transmits from the object to the image the wider pencil—has the larger aperture. If, however, the two objectives are of *different* powers, then the one which has the wider pencil relatively to its focal length has the larger aperture.

If Fig. 51 represents diagrammatically an objective of given power (or focal length*), its aperture is obviously reduced if a stop is inserted at the back of either of the lenses. The power remaining the *same*, the aperture varies with the emergent pencil.

Fig. 51.

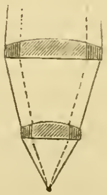


Fig. 52.

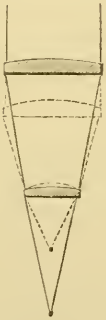


Fig. 53.

The case of *different* powers and the same or different emergent pencils is shown in Figs. 52 and 53.

If an objective of lower power (see Fig. 52) is compared with the previous one (indicated by dotted lines), the emergent pencil may remain the same, but the aperture is obviously smaller in the case of the lower power.

If an objective of twice the power of the first is taken (see Fig. 53), the emergent pencil may be only half the diameter, but the power being doubled, the aperture remains the same.

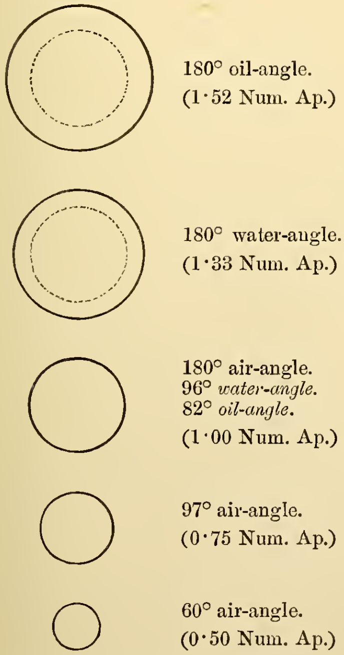
(4) Increase of Aperture with the increase in the density of the Medium.—Apertures exceeding 180° angular in air.—It is, of course, common ground with both theories of aperture that when the medium remains the same, as in the case of dry objectives, the larger the angle of the admitted pencil the larger the aperture, a

* In these diagrams there is, of course, no line which represents visibly the "focal length" of the objective, as in the case of a *single* lens. In a *compound* objective the "focal length" is arrived at by comparing the objective with a single lens of *identical power*, and the expression of the focal length of the single lens is taken as that of the objective.

dry objective of 180° air-angle having a larger aperture than one of 100° and the latter than one of 50°. The most important of the differences between the two theories arises, however, when for air is substituted a medium of greater refractive index, such as oil. This constitutes the special difficulty of the angular aperturist, for having in his consideration of aperture confined himself to the angles in front, and those being of course always limited to a maximum of 180°, he is not unnaturally led to consider 180° in air to be an absolute limit as regards aperture which cannot be surpassed by any kind of objective, a limit, moreover, imposed by fundamental natural laws in whichever way the matter is regarded.

If we examine the emergent pencils corresponding to the different angles, and, for simplicity, take objectives of the same focal length throughout, we see that the diameters of the emergent pencils of the *dry* objectives enlarge with the increase in the angles of the admitted pencils (though, as will be shown hereafter, not in the same proportion), the maximum diameter for a dry objective being obtained when the angle is 180°. If now the dry objective of 180° is replaced by an oil-immersion objective of 82°, and the angles at the radiant are increased (from 82°) as those of the dry objective were increased (up to 180°), the plain fact is that the emergent pencil *goes on enlarging in the same manner as before.* Thus if we commence with an air-angle of 10° and proceed by successive additions of 10° up to 180° air-angle, passing then to 82° balsam-angle, and again progressing up to the nearest practicable approximation to 180° balsam-angle, the emergent pencils will show a *continuous increase.** There is no break at the 180° air-angle nor does anything abnormal occur at that point, but we have a regularly progressing series from the lowest air-angle to the highest balsam-angle, the diameter corresponding to the 180° air-angle not being at the top of the series but only two-

Fig. 54.—Relative diameters of the (utilized) back lenses of various dry and immersion objectives, of the same power, from an air-angle of 60° to an oil-angle of 180°.



* If the objectives have the same focal length throughout, then, as before explained, the absolute diameter of the emergent beam is all that need be regarded; while if the focal lengths vary, it is the ratio of the diameter to the focal length that must be considered.

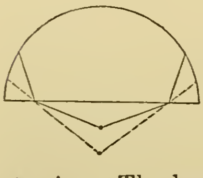
thirds of the way up, and being identical with that corresponding to 82° balsam-angle.

The diagram, Fig. 54, will serve to indicate more plainly the progressive increase in the diameters of the emergent pencils of objectives of any given power from an angular aperture of 60° in air to the highest oil-angle of 180°, and it will be seen that the pencil which emerges from a dry objective of 180° air-angle is *less* in diameter than that emerging from a water objective of 180° water-angle, or an oil objective of 180° balsam-angle, in the ratio of 1·0 to 1·33, or 1·52, the intensity of the light being approximately * the same in all. The dotted circles in the latter two cases are of the same size as that corresponding to the 180° air-angle and are added for ready comparison.

The diameter of the pencil emergent from the dry objective is, moreover, found to remain the same whether the object is mounted dry (the radiant pencil being then of large angle) or in balsam (with a much reduced angle at the radiant), so that the fallacy of the notion that the balsam cuts down not merely the *angle* but the *aperture* also becomes apparent.

When the fact of this regular increase is recognized, it is endeavoured to avoid the necessary consequence of the admission by alleging that although after the 180° air-angle is reached the emergent pencil still increases, yet that such increase does not mean the same *above* the 180° as it did *below*, for that when 180° air-angle is passed, and the balsam-angle of 82° substituted, the plane surface of the dry lens no longer exercises any reducing effect—the large air-angles in front of the lens are no longer compressed within 82° in the lens, with a necessarily reduced emergent pencil, but are allowed to expand to their full natural extent, with a proportionately enlarged emergent pencil. Thus in Fig. 55 the larger (inner) air-angle in front of the lens is refracted at the plane surface on its entrance into the glass, and becomes less than 82°. The smaller (outer) angle, assuming oil to have been substituted for air, is not reduced by refraction at the first surface, but passes into the glass with its original angular extension. The larger emergent pencil is therefore, it is supposed, fully accounted for without there being necessarily any larger aperture in the proper sense of the term!

Fig. 55.



One of the plainest of optical considerations disposes of this idea of the action of the plane surface; for, on abolishing the refraction at the *plane* surface of a dry lens by substituting a *concave* one, it is seen that the relative "opening" of the lens remains precisely the same, and is not greater.†

As, therefore, in regard to the measure of the "openings" we

* That is, less only the loss of 10 or 12 per cent. by reflection at the first surface of the front lens.

† See II. "Angular-Aperture Fallacies, No. I—The Hemisphere Puzzles, (*b*) the Concave Hemisphere."

have a continuous series from the smallest air-angle to an oil-angle of 180° (the air-angle of 180° being by no means a maximum), it is obvious that the only true and scientific notation for the comparison of apertures must necessarily be progressive also, and that no justification can be found, even as a matter of convenience, for the adoption of one which first advances from 1 to 180, and then instead of going forward goes *back* to 96 and for a second time to 180, then back once more to 127, and on for the third time to 180. If nothing more could be said against such a notation than its want of scientific precision, it might be allowed to pass with only an expression of surprise that any one could desire to retain it, but the mischief of the notation goes beyond any question of taste merely, in that it misleads the microscopist into supposing that the second and third 180°, being the same figures, represent essentially the same aperture, and so obscures the one important and practical point in connection with aperture.

Whilst the fact of the progressive increase in the diameter of the emergent beam, i. e. in the number of rays *emitted* by the objective at its *back* surface, might have been supposed to be abundant proof of itself that there must have been a similar increase in the number of rays *admitted* from the object by the *front* surface,—sufficiently disposing therefore of the principle on which angular aperture is based, and necessarily leading also to the recognition of the proper notation for aperture,—it is rarely that the angular aperturist is content with this mode of dealing with the matter. He considers that "his points" have not been directly met, which he more than suspects is due, not to the fact that they have no basis, but because they are inconveniently sound.

Before, therefore, passing to the determination of the true aperture notation, it will be desirable to show that 180° angular aperture in air does not in fact represent any natural limit or maximum, either (1) *photometrically*, or in regard to the *number of rays;* or (2) as a question of *resolution;* or (3) by virtue of what is known as "*angular grip.*" The fact also that the use of the angular expression is misleading and erroneous even in the case of the same medium, may conveniently be shown at the same time.

(5) **The Photometrical Test.—Supposed Identity of the Hemispheres in different Media.**—The point which the angular aperturist almost invariably takes up first is the photometrical one, as he considers that to furnish the most unassailable proof that 180° in air represents a "whole" which may be equalled but never exceeded.

With the same fixed illumination, 180° in oil cannot, he supposes, represent anything in excess of 180° in air as regards *quantity of light*, and pencils of any given angular extension (say 82°) in oil are necessarily only equal, therefore, in that respect to the same pencils in air. As there can be no more than the hemisphere in angular measurement, and as he assumes radiation to be the same in all media, it is self-evident, he thinks, that with the hemisphere in air we have a *whole* of light, beyond which there can be nothing. This whole can approximately be taken up by a dry lens, and being the whole, it is absurd, he contends, to speak of a water-immersion receiving *more*, and still more absurd to speak of an oil-immersion receiving *more* than that still. The numerical aperture notation, therefore, which gives a maximum of $(1 \cdot 0)^2$ for the dry objective, $(1 \cdot 33)^2$ for the water immersion, and $(1 \cdot 5)^2$ for the oil immersion, is, he thinks, not only manifestly erroneous but misleading on a vital point.

The simple answer to this view is that the angular aperturist has overlooked a fundamental optical principle, which lies at the root of any such a photometrical question, viz. that the radiation of light from an object in air, water, or oil is not identical,* but that the whole hemisphere of radiation in air is to the whole hemisphere of radiation in water or oil as the squares of the refractive indices of the media, i. e. as 1 to $(1 \cdot 33^2 =)$ $1 \cdot 77$ and as 1 to $(1 \cdot 5^2 =)$ $2 \cdot 25$. The quantity of light in pencils of different angles must be compared therefore not simply (as in the case of the same medium) by the squares of the sines of the semi-angles $(\sin u)^2$, but by the squares of *the sines multiplied by the refractive indices*, i. e. $(n \sin u)^2$.†

We have dealt with this photometrical suggestion as propounded,‡ but at the same time it must be obvious that mere quantity of light alone cannot be a sufficient basis on which to rest aperture. If it were, it could be very readily disposed of on either view of the aperture question. If the angular aperturist pointed out that when the object is in balsam and air above the cover-glass a portion of the light from the object (which is admitted when it is in air) is lost by internal reflection at the cover-glass (see Figs. 61 and 62), it would only be necessary to increase the source of light and the lost amount would at once be recovered. If, on the other hand, it was the numerical aperturist who rested the advantage of the immersion objective as regards aperture simply on the increased quantity of light which he obtained by the use of oil (say $2\frac{1}{4}$ times as great as with air), all that his opponent would have to do would be to take care and use a lamp *three* times as bright with his dry objective, and he would then have beaten the immersion objective! Or, if he used an electric light, his dry objective would of course (on the view supposed) have an "aperture" enormously exceeding that of the immersion objective with only an ordinary lamp! No increase in the amount of the illumination, however, can make a dry lens equal in performance (as regards the special function of aperture) a

* See further on this subject, III., No. 2, "Increase of Radiation in Glass, Oil," &c.

† As will be seen *infra*, p. 321, $n \sin u$ is the expression for "numerical aperture."

‡ See this Journal, *ante*, p. 150: "If they had a radiant point, whether it were "immersed in air or balsam, or any other medium, the quantity of rays from such "radiant point must be the same identically whatever the medium was;" and p. 155: "It is presumed no one will be found hardy enough to contend that the "total amount of light emitted from a radiant point under a given fixed illumina- "tion would be greater if the said radiant point were in oil or any other dense "transparent medium, than if it were in air. In point of fact we may regard "this total amount of radiant light as a fixed quantity, while the illumination of "the object remains unaltered."

wide-angled immersion lens, and difference of light cannot therefore be the *root* of the difference between the two systems.

A mode in which "quantity of light" *may* legitimately come into account in the aperture question is this:—Take a homogeneous-immersion objective of wide aperture, and use it first as a dry lens of large air-angle (say nearly 180°), and then as an immersion lens of smaller balsam-angle (say 134°). On focussing the objective on the object, and observing the emergent beam at the back, a *smaller* circle will be seen in the former case than in the latter, the two being, however, within a little (the loss by reflection) of the *same intensity*. If the diameter of the smaller circle be taken as 1, that of the larger circle will be equal to 1·4, and the amount of light received by the image in the two cases will be therefore in the ratios of the squares of the diameters, that is, as 1 to 1·96. If, then, we have two objectives of the same focal length, and one is found to take up from the object and transmit to the image a greater quantity of light than the other, the latter being placed in the most favourable circumstances of which it is capable, and the source of light remaining unaltered, it is obvious that the aperture of the former must be larger than that of the latter.

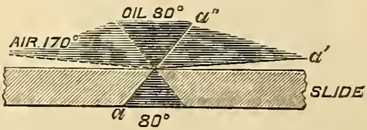
There is, however, another way in which angular aperturists sometimes put the consideration of the hemispheres in different media, which from one point of view is more rational.

Disregarding mere quantity of light as a criterion, and looking only to the *number of rays* in the plane angle, it is said that the number in angles of, say, 180° and 82° in air are equal to those in angles of the same number of degrees in oil. The number, therefore, in the pencil of 80° in Fig. 56 if oil or balsam is above the slide, is supposed to be less than those in the pencil of 170° if air is above.

This view is, however, as fallacious as the preceding.

If we take the case of *refraction*, then one of the most fundamental of optical principles shows that the *same* rays which in air occupy the whole hemisphere of 180° are compressed in a medium of higher refractive index within a smaller angle, viz. twice the critical angle. If in Fig. 56 the object is illuminated by an incident cone of rays of nearly 82° within the slide, and the slide has air above in the first case and oil in the second, it is obvious that the *same* ray which is incident on the object at nearly 41° will always emerge in air at an angle of nearly 90° (a'), and in oil at nearly 41° (a''), so that the same rays which in air are expanded over the whole hemisphere are compressed into 82° in oil, and therefore rays beyond 82° in oil must represent surplus rays in excess of those found in the air hemisphere.

Fig. 56.



If, on the other hand, the case of *diffraction* is considered, then Fraunhofer's law shows that the *same* diffracted beams which in air occupy the whole hemisphere (Fig. 57), are in oil compressed within an angle of 82° round the direct beam (Fig. 58), so that there is room for additional beams.

On this form of the angular aperture view again, therefore, the number of rays in equal (plane) angles of air, water, and oil, are seen to be as the refractive indices, that is, as 1·0, 1·33, and 1·5, and different angles are compared by the values of $n \sin u$.

FIG. 57.

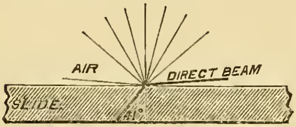
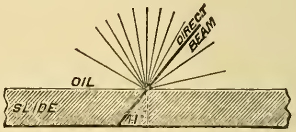


FIG. 58.

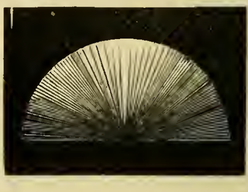


We may also point out here that even in the case of the pencils being in the *same* medium (as air), the angular aperturist, in insisting that the angles are a true measure, falls into what was formerly a very general mistake among microscopists, viz. the supposition that from a luminous surface-element there is equal intensity of emission in all directions. If this were so, then of course a given portion of the pencil taken close to the perpendicular would be identical with another portion taken at a distance from the perpendicular, provided only that the angular extension of each portion was equal. A pencil of 60° round the perpendicular (that is, of 120° angular extension) would contain 3·8 times the amount of light of one of 30° round the axis (that is, of 60° angular extension), the contents of the solid cones being as 1 : 3·8. A pencil would thus be represented by Fig. 59.

It has, however, been established for more than 100 years that this view is not correct, but that, on the contrary, the emission of

FIG. 59.

FIG. 60.



light is greater according as it takes place closer to the perpendicular, decreasing towards the horizon with the cosine of the obliquity of emission, so that the pencil is not correctly represented by Fig. 59 but by Fig. 60.

When, therefore, the same medium is alone considered, the pencils must be compared by the squares of the *sines of the semi-angles*—that is, by $(\sin u)^2$. A pencil of 120° (60° round the perpendicular) does not therefore contain nearly four times the amount of light of one of 60° (30° round the perpendicular), but three times only.*

* On this subject see further, *infra*, III., No. 1, "Difference of Radiation in the same Medium."

One of the more important *practical* mistakes which arises from this error may be seen in the case of the higher-angled objectives, to which we refer hereafter.*

From the erroneous assumption of the identity of radiation in different media spring innumerable fallacies. When in the old theory of the solar system the earth was believed to be the centre, with the sun and planets revolving round it, all kinds of complicated phenomena appeared to exist, necessitating equally complicated explanations, which gave rise to inextricable confusion. As soon, however, as the sun was made the centre, the complications existed no longer and required no explanation. In exactly the same way the angular aperturists are misled. They not only miss the whole point of the superiority of immersion objectives, viz. their larger apertures, but in consequence of missing it, and yet being obliged to recognize that they have advantages, they are induced to propound the greatest absurdities.

For instance, some will say that the advantage of immersion objectives consists almost entirely in their increased working distance and in their dispensing with the necessity for a correction collar.

Some, discovering that there is a vast increase of light with immersion objectives, explain their value to rest exclusively on the reduced amount of reflection at the plane surface of the objective, which in the case of the dry lens is said to reflect back a great part of the light. These, through the erroneous assumption with which they started, have been diverted from working out the calculation, which shows the loss of light to be only about 10 to 12 per cent.†

Others deny that immersion objectives can have any substantial advantage as regards aperture over dry objectives used on objects which are in air, as the latter radiate light up to the whole 180°, of which the dry lens can take up, say 170°, so that there is little or no room left for any improvement on the part of the immersion objectives, which are therefore supposed to show superiority over dry lenses *only in the case of the latter being used on balsam-mounted objects!* This is the view which is most frequently—we may say invariably—propounded, as it appears to be the most self-evident.

Thus, if Fig. 61 represents a pencil of 170°, radiating from an object in air, a dry objective of maximum aperture may take it up. If, however, the object is mounted in balsam, it is supposed to be so

FIG. 61.

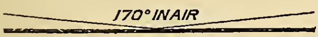


FIG. 62.

"environed" that by far the larger part of the original pencil is reflected back from the cover-glass (see Fig. 62); the dry lens, it is said, is as ready as ever to take up the original 170°, but cannot now get that pencil as it could before, when the object was in air. All it

* See *infra*, II. "Angular-Aperture Fallacies," No. 5, "Fallacies in Practical Construction."

† See *infra*, III., No. 1, "Difference of Radiation in the same Medium."

can get is the *smaller* pencil of 80° in balsam (equal, according to the angular aperture view, to 80° in air), and it is therefore supposed to be placed in circumstances in which its full powers cannot have play, in consequence of the object being in fault. The immersion objective now steps in, and by virtue of the immersion fluid above the cover-glass restores the old condition of things when there was no question of critical angles, and so is able ultimately to take up a pencil equal to, but not exceeding, that which the dry lens took up when the object was uncovered. The mistake of the numerical aperturist is (it is imagined) clear. He has treated the 80° in Fig. 62 as if it were precisely the same thing as the 170° of Fig. 61, and so is of course able to show something *more* than that when the immersion lens is used. When he thought, however, that he had 170°, he had really only 80°!

As soon as the non-identity of the whole hemispheres of radiating light is appreciated, the theory built up by the angular aperturist on this aspect of the aperture problem at once tumbles to the ground; his hemisphere in air is indeed still a *whole hemisphere*, but not a *maximum* beyond which there can be nothing more, as it is in fact exceeded by the hemisphere of water, and the latter again by the hemisphere of oil. The notion that the balsam-mounted object in Fig. 62 is guilty of some fault which cuts down the light coming to the dry lens, is proved to be groundless. The quantity of light or number of rays in the air pencil of 170° of Fig. 61 is seen to be not greater than, but only equal to, that in the balsam pencil of 80° of Fig. 62; that the balsam 170° of Fig. 62, which had been assumed by the angular aperturist to be the equivalent of the air pencil of 170° of Fig. 61, is in fact much *more*.

If, therefore, *quantity of light* were, as the angular aperturist supposed, a proper, and not an insufficient basis for determining the aperture question, the angles alone cannot be taken for the determination, as the quantity in any given angles in air, water, or balsam must be compared by the values of $(n \sin u)^2$, n being the refractive index of the medium and u the semi-angle of aperture. The *number of rays* in the plane angles are compared also by the values of $n \sin u$. In neither case does 180° in air represent a maximum.

(6) The "Resolution" Test.—The contention of the angular aperturist here is that the resolving power of an objective must vary in accordance with the angle, and reach a maximum at an air-angle of 180°.

In the case we have just considered, he had no excuse for not recognizing the obvious fact that quantity of light was an entirely insufficient basis on which to discuss aperture, or for not performing the simple experiment ready at his hand, which would have showed at once that the light transmitted from the smaller balsam pencil was not in fact, as he had assumed it to be, less than that transmitted by the larger air pencil. In the case, however, of the resolving power of objectives, there is somewhat more excuse, for whilst it is seen that the resolving power increases with increasing angles in the case of a dry objective, there *seems* to be a falling off when for the dry angle of 170° is substituted the balsam-angle of 80°.

Thus an oil-immersion objective of 100° angular aperture (1·16 num. ap.) has in reality a greater resolving power than a dry objective of 170° angular aperture (0·99 num. ap.). But when an object is observed, first dry and then in balsam, its structure is much less visible in the latter case than in the former, whence it is concluded that as regards resolving power, at any rate, the greater angle has the greater effect.

The diminished visibility is, however, conditional, and has nothing to do with the resolving power of the objective, as it exists only in the case of those objects whose refractive indices nearly approach that of the medium in which they are immersed, whereby their minute structure is rendered the less distinct. As Mr. Stephenson has pointed out,* the image of the balsam-mounted object has become fainter in consequence of this nearer approximation to equality of the diatomaceous silex and the balsam of the mounting; the markings, whatever they may be, are less pronounced than when in air, the visibility being proportional to the difference between the refractive indices of the object and the mounting medium.

A simple experiment readily shows whether the reduced visibility of the object is due to the cause we have mentioned or to the reduction of the angle. Substitute for the balsam a mounting substance of greater refractive index. The angle is now still *more reduced*, and the object should be still *less* distinct if the view contended for were correct. In fact, it is *more* distinct, and it is obvious therefore that the reduction of the angle has nothing to do with the matter.

Eliminating therefore all exceptional circumstances and dealing with resolving power in its essential conditions, it is found both by experiment and by theory that the resolving power of objectives does not vary, as the angular-aperture theory supposes, with the *angles*.

It is unnecessary to reproduce here the demonstrations which show that the microscopical image of minute objects is not, as was for so long supposed, a *dioptric* but a *diffraction* image, as it is referred to hereafter.† It is sufficient for the present purpose to note that just as a grating produces a central uncoloured image and lateral spectral images of a candle-flame, so a diatom will produce at the back of the objective central and lateral images of the source of light, more and more of the structure being revealed according as a greater number of the diffraction spectra are taken up by the objective. Thus, as we have seen, a dry objective of 180° will give an emergent beam of limited diameter, and will then admit a given number of diffraction spectra on each side of the central uncoloured image. A water-immersion objective of wide angle will give an emergent beam of greater diameter, by means of which additional diffraction spectra on either side may be brought into the field with increased resolution of the object. An oil-immersion objective giving a still larger emergent beam will, in the same way, bring into the field still more diffraction spectra with further advanced resolution. The divergence of the diffraction spectra

* See this Journal, iii. (1880) p. 564.

† See IV., *infra*, p. 347.

being (in accordance with Fraunhofer's formula) proportional to the sine of the semi-angle multiplied by the refractive index of the medium, $n \sin u$ † is the true measure of the resolving power of an objective; so that 180° air-angle (= 1 num. ap.) represents not the whole (= 1·5 num. ap.) but only two-thirds of the total possible effect as regards resolving power.

Sometimes it is objected, as it was in the recent discussion,‡ that resolving power must not be dealt with in considering aperture. It is somewhat difficult to appreciate how it can be consistently, or even seriously, suggested that resolving power is to be excluded from a discussion of the aperture question from the point of view of *angular* aperture, for even in the height of the predominance of that theory it was resolving power, and resolving power alone, that was always accepted as representing the proper function of increased aperture.

The *true* function of aperture is in fact to be found not merely in resolving power, but in the increased and more perfect *delineating power* of the Microscope (to use Professor Abbe's term), i. e. the power of the Microscope to show things *as they are*. This view is, however, founded on considerations which the angular aperturist necessarily does not accept, and which to him has always been represented only by the more limited term of "resolving power," which is *one* only of the particular manifestations of delineating power. When, therefore, he does not object to the use of the expression of $n \sin u$ as the proper expression for resolving power, he may well be asked to define those *other* benefits, *not* being resolving power, which he contends are attendant upon increased aperture, and for which the *angle* is alleged to be the correct expression.

(7) The "Angular Grip."—Having seen that illuminating power and resolving power vary not as the angles, but as $(n \sin u)^2$ or $n \sin u$, we reach the last point suggested by the angular aperturist in support of the supposed maximum of 180° in air, which has come to be known as the "angular grip" theory. If "angular grip" existed in reality, the use of the angular expression would of course be established, as it must obviously increase with the angles and attain a maximum at 180° whether in air or any other media.

Taking Figs. 61 and 62, and forgetting that it was they themselves who raised the photometrical question or the resolution question and at first based all their argument on that alone, they say, "Your demonstration has not touched the real point at issue, which has nothing to do with greater or less amount of light, or with greater or less resolving power. Is it not clear that the pencil in Fig. 61 is of larger angle than that of Fig. 62."

If it is explained that no objection is intended to be made on that point, and that every one must readily admit that the pencils *are* different as regards angular extension, the angular aperturist exclaims triumphantly, "If you admit that the angular extension of the pencils at the object is different—that the pencil of 180° in Fig. 61 is in that respect larger than the pencil of 82° in Fig. 62—I have proved my case. The angular grip of the object is greater with the 180° than with the

† i. e. the "numerical aperture." ‡ See this Journal, *ante*, p. 160.

82°. In the one case the light comes with an obliquity of 90°, whilst in the other case it has only an obliquity of 41°, and the object can of course be seen more completely and distinctly by reason of the greater obliquity.* It cannot matter whether the medium is air or balsam; the obliquity *per se* is obviously not altered in the least degree by the change of medium."

For years the ablest and most experienced microscopists in England, and indeed everywhere, accepted the doctrine without question that there *was* a special virtue in the increased obliquity of the light incident on and emanating from the object, and not only so, but pointed out the reason for the (supposed) fact, explaining it to depend upon what were termed "shadow effects," i. e. in the same way as the inequalities on the face are better brought out by oblique than with direct light. This process of discovering a reason for a supposed fact prior to any verification of the fact itself, is only paralleled by the famous problem said to have been propounded by Charles II. to a learned Society—"*Why* does a vessel of water with a fish in it weigh no more than it did when there was no fish?"

About thirteen years ago it occurred to Professor Abbe to investigate the reason for the supposed value of obliquity *quâ* obliquity, and he naturally proposed in the first place to consider anew the grounds on which the view had been based when originated. To his surprise he found that no attempt had really been made to investigate the matter; that there was no theory and no experiment to support the alleged fact, which had been quietly assumed by every one to *be* a fact, no one knew how, except from some fancied analogy to ordinary vision, regardless of the different conditions of microscopical vision, or probably from incomplete generalization from the fact that a pencil of 170° does show minuter structure than a pencil of 80° in the same medium; but that, like the fish problem, it had not occurred to any one that the task of verifying the existence of the assumption should have preceded any reasoning upon it or attempts to explain it.

A long course of experiments extending over several years was undertaken by Prof. Abbe, which established the fallacy of the old view, and by force of the necessity for explaining intelligibly the real specific function of increased aperture, led to the enunciation of the most important theory that has ever been propounded in regard to the Microscope itself, viz. the Abbe theory of microscopical vision to which we refer hereafter.†

The cardinal point in Prof. Abbe's experiments was the discovery that the utilization of increased aperture depends *not on the obliquity of the rays to the object* (as had been assumed), *but on their obliquity to the axis of the Microscope.*

* Sometimes the *opposite* view is put forward, viz. that by the increased angle of aperture a *less* perfect image of the object is obtained in consequence of the unnatural character of vision with large angles, which is supposed to produce distortion and indistinctness not found in ordinary vision with the naked eye where small-angled pencils are in question.

† See IV., *infra*, p. 347.

It was shown that both theory and experiment may be applied to prove that the mere angular extension of the pencils—obliquity *quâ* obliquity—so far from being of importance, is absolutely indifferent; that the greater obliquity of the rays incident on or emitted from the object is not and cannot be *of itself* an element of the optical performance of greater aperture. If it were, the necessary consequence would be that the same increase of optical performance which is obtained by a greater aperture, must be equally obtained with a lesser aperture, by *inclining* the object to the axis of the Microscope. Now this is of course so in regard to the shadow effects of *coarse elements* which are plainly seen by aperture angles of a *few* degrees. But this is not the performance for which we require aperture; the only essential practical function of increased aperture is to afford vision of *minute* elements or structures which are not seen by small-angled pencils. When, however, we have objects which are not resolved by direct light and in the ordinary position by an aperture of say 80°, but are *readily resolved under the same circumstances* by an aperture of 90°, they are not resolved with the 80°, even if we incline the preparation to any angle, though a few degrees of inclination would give the same increase of obliquity as regards the object which the increase of aperture gave.

The experimental consideration was seen to be supported by theory. Whenever the linear dimensions of objects are reduced to *small multiples* of the wave-lengths, all shadow and similar effects must cease. The reason is similar to that which shows why objects of not more than a few feet in diameter do not give a sensible *acoustic* shadow behind them, but only those whose dimensions are *large* multiples of the sound-waves. The waves of both sound and light *pass round* an obstacle which is not much greater than their length.

The supposed advantage of "angular grip" is also sometimes based on the contention that the increase in obliquity obtained by wide angles produces an effect of "solidity." This idea of solidity obviously arises from the supposition that the different perspective views of a preparation which correspond to the different obliquities produce the same result as if they were seen separately by different eyes, as is the case in the binocular Microscope. In reality the various views are united on one and the same retina, and as the image is nevertheless perfectly delineated, the idea of solidity must be erroneous.

The true effects of obliquity are proved by Professor Abbe's experiments (which every microscopist can try for himself without any apparatus costing more than a few shillings), to depend not on the *angles* but on the *numerical equivalents* of these angles (n sin u), and thus an obliquity of 41° in balsam must have the same effect as an obliquity of 90° in air.

If the angular aperturist is still not satisfied that there can be no virtue in mere obliquity *quâ* obliquity, then it is of course for *him* to bring forward the grounds, whether theoretical or experimental, by which he establishes the virtue of the obliquity—that the large air-pencil of 180°, carrying with it demonstrably no greater quantity of light, and equally demonstrably no more resolving power than the small balsam-pencil of 82°, yet has *some* virtue that prevents the latter being treated as its equivalent. We are entitled to ask *what* this virtue is, and to be shown that it is not a mere fancy. If it is asserted that there must necessarily be a loss in passing from 180° air-angle to 82° balsam-angle (a large difference in angular extension), surely this loss can be shown or defined? At least, some intelligible explanation can be given of its essence and existence—of the optical theory on which it is based or the experiments by which it is supported?

(8) **Numerical Aperture.**—Having now shown that in whatever way the matter may be regarded the expression of the degrees in the angles is not a correct method of comparing apertures, and that 180° in air is not a maximum, we are in a position to resume the consideration of the notation to be adopted for the proper estimation of aperture, and this it will be seen is essentially numerical aperture, which is however supposed by the angular aperturist to be a fanciful notation, not founded on any known natural phenomenon, so that whether a person adopts it, or continues to use the expression of "angular" aperture, is purely a question of taste, like the adoption of the Fahrenheit or Centigrade scales for the thermometer.

Aperture, in its true and legitimate meaning of "opening," depends, as we have seen, on the ratio between the clear opening of the objective and the power—a ratio which increases progressively from the lowest angular aperture of a dry objective to the highest angular aperture of an oil-immersion objective. The expression for the ratio of the semi-diameter of the emergent pencil to the focal length is $n \sin u$, n being the refractive index of the medium and u the semi-angle of aperture. It is simply this expression which is the *numerical aperture*, and which is therefore the true measure of the relative apertures of objectives of all kinds.

We have also seen that whether we consider the amount of light in the pencils, the number of rays in the plane angle, or the resolving power, it is $n \sin u$ (or its square) which affords the only correct comparison.

The expression $n \sin u$.

We add here one of the forms of the deduction of the expression $n \sin u$ which, though not the most strict, is one of the simplest. It establishes two points. 1st. That the angle alone ($2u$) can never correctly define aperture, for equal apertures always require equal values of $n \sin u$, and different apertures different values; so that this expression (i. e. a function of the semi-angle compounded with the refractive index of the medium, and not the angle itself) is necessarily the adequate measure of aperture in general; and 2nd, that a dry objective cannot have so large an aperture as a wide-angled immersion objective.

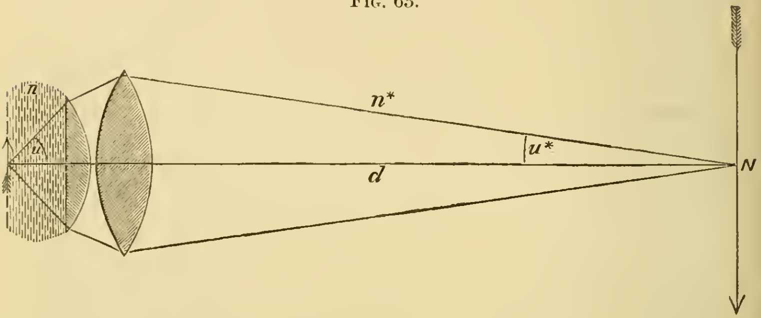
Let Fig. 63 represent any objective collecting a pencil exceeding 82° in balsam with any desired amplification of the image, and any desired distance of the image (i. e. length of tube), let u be the semi-angle of the admitted pencil within a medium of refractive index n ($= 1 \cdot 5$ if it is oil), N the amplification of the image which is always in air, and u^* the semi-angle of the emergent pencil which depicts the image. According to the law of aplanatic convergence †—

$$\frac{n \sin u}{n^* \sin u^*} = \text{N},$$

or, as $n^* = 1$ for air,

$$\sin u^* = \frac{n \sin u}{\text{N}}.$$

Fig. 63.



† It may be useful to give the history of this law. It has its origin in a publication of Lagrange ("Sur une loi générale d'optique," 'Mémoires de l'Acad. de Berlin,' 1803), where he first showed that there is a fixed relation between the amplification and the divergence or convergence of the rays at any pair of conjugate foci, provided (1) both foci are in the *same* medium, (2) the system is composed of infinitely thin lenses, and (3) the pencils are *infinitely narrow*, i.e. the angles of convergence very small.

The formula then being $\frac{u}{u^*} = \text{N}$ for every system of infinitely thin lenses (n and n^* being equal).

In the famous reproduction (or rather reformation) of the Gaussian theory in the 'Physiologische Optik' (1866), Helmholtz showed that this formula holds good for every composition of an optical system, and for *different* media, n and n^*, on the general supposition, however, of the Gaussian theory—*infinitely narrow* pencils. The generalized law therefore became

$$\frac{n\, u}{n^*\, u^*} = \text{N}.$$

Instead of u and u^* Helmholtz took the tangents of these angles (which is the same thing as long as the angles are very small), and in this shape the proposition first obtained its characteristic feature, showing the existence of a general fixed relation between amplification and divergence or convergence at conjugate foci entirely independent of the elements of the systems, and indicating a different equivalent of equal angles in different media.

The next step was to apply this formula to systems with *wide-angled* pencils; and in 1873 Prof. Abbe signalized the fact that in the case of aplanatic foci the convergence or divergence of the rays does not vary with the angles or with the tangents, but with the *sines*. The same result was proved independently by Prof. Helmholtz by a different method, and was published by him six months after that of Prof. Abbe.

At a later period Prof. Abbe has expressly called attention to the bearing of the law of the sines to the practical performance of wide-angled systems, and

Thus the divergence or convergence of the emergent pencil is completely defined by N, u, and n, without requiring any knowledge of the focal length of the system, or of the distance d at which the image is formed.

Now there is of course loss of aperture (1) when there is a loss of amplification N, while u^* remains the same, and (2) when there is a reduction of u^*, while N remains the same. For these reasons:— With any given distance d of the image from the back lens, $d \tan u^*$ is the clear available semi-diameter of the back lens. If now the objective gives less amplification (at the same distance d) while u^* is not greater, we should have a *lower-power* objective with the *same* clear diameter of the back lens, and this is necessarily loss of aperture. If, on the other hand, the system gives a narrower pencil (diminished u^*) while N is not greater, we should have an objective of the *same power* giving a narrower emergent pencil (i. e. with a *smaller* clear diameter of the back lens), and this is necessarily loss of aperture also.

Therefore, constant aperture requires the condition of constant amplification N for the same distance d (i. e. for the same length of tube) if u^* is the same, and of constant angle u^* of the emergent pencil if N is the same. It follows, therefore, that the remaining element in the formula which relates to the anterior pencil ($n \sin u$) must also be constant; so that there is always loss of aperture whenever the product $n \sin u$ has a smaller value, as this would require either a smaller N or a smaller u^*.

If now in an immersion objective, with balsam or oil in front, u is greater than the critical angle of the medium, $n \sin u$ will be > 1 (for n is $1 \cdot 5$ and $\sin u$ is at least $\cdot 667$). It will be impossible to obtain the same value, if the front medium is changed for *air*, for n being then only $= 1$, $\sin u$ must be greater than 1, that is an angle with a sine > 1, which is absurd!

No alteration of the optical system is of any avail because the formula holds good for every system.

Therefore no dry objective can be equal in aperture to a wide-angled immersion objective in which $n \sin u$ is > 1—i. e. the balsam angle of which exceeds 82°.

It follows also that equal or different apertures always require equal or different values of the expression $n \sin u$, which is therefore the proper expression for aperture in general.

pointed out its connection with the essence of aplanatism. He indicated at the same time a simple experimental demonstration of the law.

For the literature on the subject, see the following:—

Abbe, "Beiträge z. Theorie d. Mikroskops," &c., Arch. f. Mikr. Anat., ix. (1873) p. 420.

Helmholtz, "Die theoretische Grenze für die Leistungsfähigkeit des Mikroskops," Poggendorff's Annal. Jubelband (1874) p. 566.

Abbe, "Ueber d. Bedingungen d. Aplanatismus d. Linsensysteme," 'Carl's Repertorium für Experimentalphysik,' xvi. p. 303. Conf. this Journal, iii. (1880) p. 509.

The formula in question (the outcome of the combination of the Lagrange-Helmholtz law with the law of aplanatic convergence) is the basis of all investigations on dioptrical questions which deal with wide angles.

*

"Diagram" of Numerical Aperture.

Requests have been made to *see* "numerical aperture." There is the same difficulty about this request as about one requiring to be shown the equator, or the meridian of Greenwich, or the North Pole, as all these expressions, equally with numerical aperture, require the aid of the mental rather than the bodily eye. Applying, however, the only method by which the equator, for instance, could be "*seen*," we may refer to the diagram, Fig. 54 (see p. 309), which shows the diameters of the pencils emerging from the back lenses of dry, water-immersion, and oil-immersion lenses with angular apertures of 60°, 97°, and 180° air-angle, 180° water-angle, and 180° oil-angle, assuming the power of all the objectives to be the same. We add here Fig. 64 (on the same scale), which gives the diameter of the back lens of an objective whose front lens is supposed to be made of a substance whose refractive index = 2·5, i. e. about that of the diamond. The dotted circle denotes the aperture corresponding to 180° in air, and the diagram shows therefore the advance in aperture that would be possible if substances of that refractive index could be made available.*

Fig. 64.

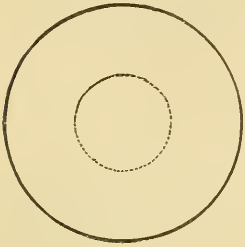


Table of Numerical Apertures.

The table of numerical apertures (calculated by Mr. Stephenson), as inserted on the wrappers, has not previously been given in the body of the Journal; † we now subjoin it for permanent reference. The first column gives the numerical apertures from ·40 to 1·52. The second, third, and fourth the air-, water-, and oil- (or balsam-) angles of aperture corresponding to every ·02 of numerical aperture from 47° air-angle to 180° balsam-angle. The sixth column shows the theoretical resolving power in lines to an inch, the line E of the spectrum about the middle of the green, $\lambda = 0 \cdot 5269\ \mu$ being taken). We have added a fifth column of "Illuminating power" (= a^2), though, for the reasons we have given above, it is of comparatively minor importance.

The sum of the whole, therefore, is that if the medium remains the same, apertures are correctly compared by the sines of their semi-angles; or if the media are different, by those sines multiplied by the refractive indices of the media—the value of $n \sin u$, or the numerical aperture, always measuring the relative diameters of the "openings" of objectives, whether the object is in air, water, oil, or any other substance.

Thus with three objectives, one a dry with an angular aperture of 74° (air); a second, a water-immersion of 85° (water); and a third, a homogeneous-immersion of 118° (balsam), their relative "openings" are shown at a glance when the numerical apertures

* The refractive indices of the cover-glass and the immersion fluid must of course also = 2·5.

† See the first form of the Table, this Journal, ii. (1879) p. 839.

Numerical Aperture. ($n \sin u = a$.)	Angle of Aperture of Dry Objectives. ($n = 1$.)	Angle of Aperture of Water-Immersion Objectives. ($n = 1 \cdot 33$.)	Angle of Aperture of Homogeneous Immersion Objectives. ($n = 1 \cdot 52$.)	Illuminating Power. (a^2.)	Theoretical Resolving Power, in Lines to an Inch. ($\lambda = 0 \cdot 5269\ \mu$ = line E.)
1·52	..	..	180° 0′	2·31	146,528
1·50	..	..	161° 23′	2·25	144,600
1·48	..	..	153° 39′	2·19	142,672
1·46	..	..	147° 42′	2·13	140,744
1·44	..	..	142° 40′	2·07	138,816
1·42	..	..	138° 12′	2·02	136,888
1·40	..	..	134° 10′	1·96	134,960
1·38	..	..	130° 26′	1·90	133,032
1·36	..	..	126° 57′	1·85	131,104
1·34	..	..	123° 40′	1·80	129,176
1·33	..	180° 0′	122° 6′	1·77	128,212
1·32	..	165° 56′	120° 33′	1·74	127,248
1·30	..	155° 38′	117° 34′	1·69	125,320
1·28	..	148° 28′	114° 44′	1·64	123,392
1·26	..	142° 39′	111° 59′	1·59	121,464
1·24	..	137° 36′	109° 20′	1·54	119,536
1·22	..	133° 4′	106° 45′	1·49	117,608
1·20	..	128° 55′	104° 15′	1·44	115,680
1·18	..	125° 3′	101° 50′	1·39	113,752
1·16	..	121° 26′	99° 29′	1·35	111,824
1·14	..	118° 00′	97° 11′	1·30	109,896
1·12	..	114° 44′	94° 56′	1·25	107,968
1·10	..	111° 36′	92° 43′	1·21	106,040
1·08	..	108° 36′	90° 33′	1·17	104,112
1·06	..	105° 42′	88° 26′	1·12	102,184
1·04	..	102° 53′	86° 21′	1·08	100.256
1·02	..	100° 10′	84° 18′	1·04	98,328
1·0	180° 0′	97° 31′	82° 17′	1·00	96,400
0·98	157° 2′	94° 56′	80° 17′	·96	94,472
0·96	147° 29′	92° 24′	78° 20′	·92	92,544
0·94	140° 6′	89° 56′	76° 24′	·88	90,616
0·92	133° 51′	87° 32′	74° 30′	·85	88,688
0·90	128° 19′	85° 10′	72° 36′	·81	86,760
0·88	123° 17′	82° 51′	70° 44′	·77	84,832
0·86	118° 38′	80° 34′	68° 54′	·74	82,904
0·84	114° 17′	78° 20′	67° 6′	·71	80,976
0·82	110° 10′	76° 8′	65° 18′	·67	79,048
0·80	106° 16′	73° 58′	63° 31′	·64	77,120
0·78	102° 31′	71° 49′	61° 45′	·61	75,192
0·76	98° 56′	69° 42′	60° 0′	·58	73,264
0·74	95° 28′	67° 36′	58° 16′	·55	71,336
0·72	92° 6′	65° 32′	56° 32′	·52	69,408
0·70	88° 51′	63° 31′	54° 50′	·49	67,480
0·68	85° 41′	61° 30′	53° 9′	·46	65,552
0·66	82° 36′	59° 30′	51° 28′	·44	63,624
0·64	79° 35′	57° 31′	49° 48′	·41	61,696
0·62	76° 38′	55° 34′	48° 9′	·38	59,768
0·60	73° 44′	53° 38′	46° 30′	·36	57,840
0·58	70° 54′	51° 42′	44° 51′	·34	55,912
0·56	68° 6′	49° 48′	43° 14′	·31	53,984
0·54	65° 22′	47° 54′	41° 37′	·29	52,056
0·52	62° 40′	46° 2′	40° 00′	·27	50,128
0·50	60° 0′	44° 10′	38° 24′	·25	48.200
0·48	57° 22′	42° 18′	36° 49′	·23	46.272
0·46	54° 46′	40° 28′	35° 14′	·21	45,344
0·44	52° 12′	38° 38′	33° 39′	·19	42,416
0·42	49° 40′	36° 49′	32° 5′	·18	40,488
0·40	47° 9′	35° 0′	30° 31′	·16	38,560

0·60, 0·90, and 1·30, are given, and it is seen also by how much they fall short of, or exceed 1 (= 180° angular aperture in air). Compare with these figures those denoting the angular aperture!

"Numerical aperture," therefore, so far from being a fanciful arbitrary notation, expresses the plain fact that we want to understand, viz. how does the relative "opening" of any given objective—i. e. its aperture or the capacity of the objective for receiving rays from an object—stand in relation to that of another objective (whether dry, water-immersion, or oil-immersion)? Has it the *same* opening, or a *larger* or *smaller* one?

II. Angular-Aperture Fallacies.

We have now dealt with the insufficiency of the angular-aperture theory from all the points on which it has been attempted to base it: showing, 1st, the fallacy of the photometrical test and of the supposed identity of the hemispheres in different media, so that 180° in air does not represent the "whole" contended for; 2nd, that resolving power is not proportional to the angles nor attains a maximum with 180° in air; 3rd, that there is no virtue in greater or less "angular grip"; and 4th, that numerical aperture is the only scientific notation for the comparison of the "apertures" of objectives, using the term in its true sense as the capacity of an objective for admitting rays from an object.

We propose now to deal with some special fallacies of angular aperture which could not be conveniently included in the preceding pages, and the following notes meet some of the difficulties which we have from time to time met with in discussing the aperture question. They are none of them imaginary, but all have actually occurred, and not only so, but have been really felt to be difficulties. It is easy to be surprised, after the explanation is given, that they *could* have appeared as "difficulties"; but as they have occurred more than once already, they are very likely to occur again, and we do not think therefore that the space devoted to them is wasted.

(1) The Hemisphere Puzzles.—

(a) *The Convex Hemisphere.*

This puzzle is now hung up in the Society's Library, and will no doubt be a source of wonder to microscopists of the future that their forefathers could ever have been puzzled by it. It has been suggested in various forms, the most notable of which is the following.

The cardinal fallacy of the angular aperturist has always been the idea that when an object is mounted in balsam the *aperture* of the dry objective is "cut down." Thus the aperture of a dry objective of say a $\frac{1}{4}$ inch of 90° (air-angle) used upon an object in air would, it was thought, be largely "cut down" if the object were placed in balsam, which would reduce the angle at the radiant to say 55°, the air above the cover-glass preventing part of the rays formerly emitted from emerging.* The aperture of a $\frac{1}{4}$-inch immersion objective of 90°

* Cf. Figs. 61 and 62.

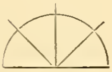
balsam-angle would not of course be similarly "cut down," the air-film having been replaced by the immersion fluid.

The problem, therefore, was how to restore the "cut down aperture, so that the dry objective with the balsam-mounted object might be brought back again (as it was supposed) to the condition in which it was when the object was dry, with its "undiminished" aperture bearing upon the object.

FIG. 65.

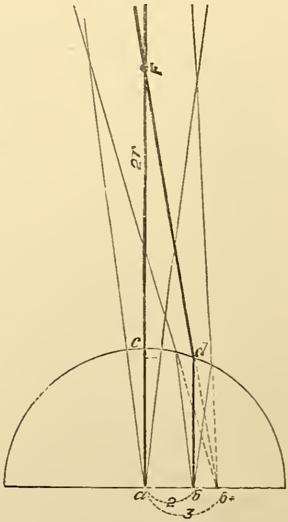
The device hit upon was the convex hemisphere. If Fig. 65 represents the rays radiating from a given point in air, their direction will remain the same (as shown in Fig. 66) if a glass hemisphere is so placed that the radiant point is at its centre. A hemisphere was therefore said to be merely a "radiating lens."

FIG. 66.



A small glass hemisphere was placed over the balsam-mounted preparation, and attached to it with balsam. The angle of the radiant pencil (when the dry objective was focussed upon the object through the hemisphere) was now of course as large with the balsam-mounted preparation as it was originally when the object was dry, and a dry objective was therefore, it was supposed, shown to be capable of having as large an aperture with a balsam-mounted object as with a dry one, all that was required being to bring the object under suitable conditions!

FIG. 67.



Now, strange to say, the propounders of this problem had actually overlooked the fact that the hemisphere magnified the object $1\frac{1}{2}$ times,† so that the objective was no longer a $\frac{1}{4}$ inch, but had been converted into a $\frac{1}{6}$ inch, utilizing, however, not a smaller but the same back

† The notion that the hemisphere does not magnify evidently originated from considering only the point at the exact centre. From this point all rays pass out radially without refraction.

If, however, not a *point* but an *object* of definite dimensions is considered, as in Fig. 67, it is seen that the hemisphere magnifies in proportion to its refractive index.

The ray $a\,c$ is transmitted in a straight line, but a parallel ray $b\,d$, from an adjoining *excentrical* point, is refracted to the principal focus F. In a lens of refractive index $n = 1 \cdot 5$ the distance of the principal focus from the vertex c is $= 2\,r$. Therefore the virtual point of divergence of the excentrical pencil from b is transferred to b^*. As:—

$$\begin{aligned} a\,b^* : a\,b &= \mathrm{F}\,a : \mathrm{F}\,c \\ &= 2\,r + r : 2\,r \\ &= 3 : 2. \end{aligned}$$

Thus the line $a\,b$ is seen magnified $\frac{3}{2}$ times.

combination. Being therefore a higher power ($\frac{1}{6}$ inch) with the same back combination and diameter of the emergent pencil as the lower power ($\frac{1}{4}$ inch) it necessarily had a *larger aperture* than the latter!

We doubt whether there is on record any more extraordinary scientific fallacy than this, propounded as it was with all possible seriousness. That we may not be supposed to intend any personal reflection on *one* side, we may point out that the strangeness is, if anything, enhanced by the fact that the other side did not discover the mistake, and considerations and arguments have been brought forward on the action of such a hemisphere involving the greatest absurdities. Had the true position been appreciated, it would at once have been seen that the angular aperturists had in fact given a clear and simple demonstration that *their own view was wrong*, for they had shown that equal angles in air and glass gave not the same but different apertures, the latter being the larger. The dry objective when used with the hemisphere was of course converted into a true immersion objective, the balsam-angle of which was the same as the original air-angle of the dry objective.

This problem may also be used to demonstrate that an immersion objective can have an aperture exceeding the maximum aperture of a dry objective. For it follows from the formula (p. 322) that no dry front can exist which can be substituted for the hemispherical immersion front without loss of aperture or loss of amplification; for if there could, such a dry front must give an emergent pencil of 90° *under an amplification of* 1·5. The formula, however, shows that the widest cone which can be got out of any lens receiving the rays from air under an amplification of 1·5 is *circa* 82° only.

(b) *The Concave Hemisphere.*

This arises in the following way.

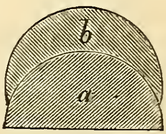
When the angular aperturist is confronted with the fact that the emergent beam of a wide-angled immersion objective is wider than that of any dry objective, he contends that whilst admittedly when the object is in air, a wide emergent beam from an angle of 120° contains more rays than a narrower one from an angle of 60°, yet that when the front medium is changed the increase in the emergent beam can no longer be treated as representing an increase in the rays taken up from the object, for that must necessarily be so in consequence of the action of the plane surface of the front lens, which reduces an air-pencil of 180° into one of 82° only, when it passes into the glass (cf. Fig. 55). With the immersion fluid, however, the reducing action of the plane surface is abolished—the pencils from the radiant are no longer reduced to 82°, but can expand to the fullest extent which the objective will allow, the expanded pencil, however, still representing, it is supposed, no more than the reduced one.

As proof of this view, he considers a dry objective (say $\frac{1}{6}$ inch, of 140° air-angle) with a plane front. The pencil of 140°, after being contracted within the front to one of 76·5° ($n = 1·52$), will require, in order to be transmitted through the system, a given clear diameter of the back combination. Assuming the plane surface removed, and a concave one with the centre of curvature at the radiant substituted, he sees that *now* the back combination is fully occupied by a pencil of 76·5°; so that the former pencil of 140° would, in order to be transmitted, require a much wider back lens. Hence he concludes that abolishing the refraction at the front surface produces loss of aperture with one and the same opening, or necessitates increase of opening for one and the same aperture; and as the immersion fluid has the same effect as the substitution of the concave surface of admission, the result must also be the same. The wider emergent beams of immersion objectives are therefore shown, it is supposed, not to denote in reality larger apertures!

He has, however, fallen into the same mistake in principle as that with the convex hemisphere. When the concave was substituted for the plane front the *power* of the objective was *reduced* in the ratio of $n:1$; and as the clear opening is not increased, loss of aperture has arisen from *loss of power*, but *not* from *loss of the refraction* in front. As soon as the original power of the objective is restored by deeper curvatures of the posterior lenses, the original opening would be sufficient to transmit the pencil of 140° air-angle, notwithstanding its greater expansion in the front lens. Thus it is obvious that the anterior refraction cannot account for the smaller openings of dry objectives in comparison with equal power immersion objectives of equal angular aperture.

The loss of amplification by the concave surface of admission is of course reduced to the fact that the hemisphere amplifies an object at the centre. We obtain the lens *b* (Fig. 68) with the concave front-surface by *cutting out* a hemisphere *a* of the same radius, and as this has previously amplified the object by *n* diameters, that amount of amplification is lost when it is taken away.

FIG. 68.



(c) *The Hemisphere as a Condenser.*

There is another phase of the hemisphere puzzle which we can vouch for as having very much puzzled some angular aperturists.

Comparing the case of an object on an ordinary plane slide (Fig. 69) turned with its under surface to the heavens, and another object on a slide with a portion of a sphere cemented on, the object being at the centre of the sphere (Fig. 70), it is said that the former object receives more light than the latter. The former receives light from the whole 180° of the heavens—that is, all the light from between

FIG. 69.

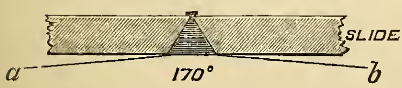
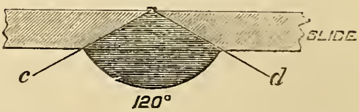


FIG. 70.



the points *a* and *b*; the other object only receives light from between the points *c* and *d*, which is a less angular range than *a* and *b*. All rays from beyond *c* and *d* do not fall upon the sphere, and therefore not reaching the object, there must be less illumination, unless the lens could be enlarged to a complete hemisphere.

This consideration, however, overlooks the fact that a hemisphere produces *concentration* (or condensation) of the light at its centre (which does not of course exist in the case of Fig. 69). Though rays which are directed to the centre are not refracted, the fact is, nevertheless, that the *same* rays which from any point (or small element) of the heavens reach a circle of definite diameter δ of the object in Fig. 69, are, by the action of the sphere, collected on a circle of smaller diameter $\frac{\delta}{n}$ in Fig. 70 (n being the refractive index of the lens), and consequently the original circle δ under the sphere receives from every point of the heavens, between c and d, n^2 times more light than an equal circle of the object on the plane slide. This may be proved by a similar dioptrical demonstration to that given above.

It is thus seen that the object, in the case of Fig. 70, may obtain the same light from a *portion* of the heavens as in Fig. 69 is obtained from the whole. If the angle between c and d should be 82°, the illumination of the object would be the same exactly. If that angle should be nearly 180° (in the case of a very large hemisphere and a very thin slide), the illumination in Fig. 70 would be n^2 times greater than in Fig. 69.

(2) **Illumination Fallacies.**—We have called these "illumination fallacies" for want of a better term, although that does not quite express their true character. We give the substance, however, as it has been put to us on many occasions with slight variations.

Assume the full apertures of a dry and an immersion objective to be illuminated from beneath the slide, so that we have a pencil above the slide of 170° in air in the first case, and 140° in oil in the second, the source of light remaining unaltered. Figs. 71 and 72 will then show the illumination which would be required to fill the apertures of the dry and immersion objectives respectively.

(a) When the angular aperturist recognizes that there is more light in Fig. 72, he then says that the conditions of the dry and immersion objectives are not the same, that the immersion objective

Fig. 71.

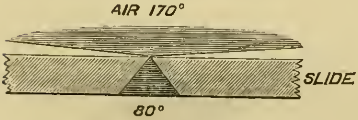
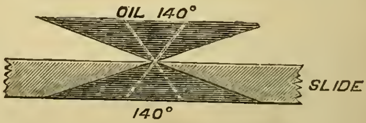


Fig. 72.



has been "allowed to get more light" than the dry objective. If it is only allowed to have a pencil of 80°, like the dry objective, its aperture will be found to be not greater but only equal.

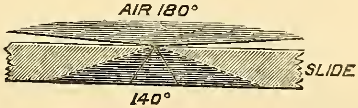
But if it is admitted that the illuminating pencil of 140° in Fig. 72 contains more light than that of 80° in Fig. 71, and that the former must be cut down to 80° also to establish equality, what becomes of the original argument? If the 140° in the glass of Fig. 72 is more than the 80° in the glass of Fig. 71, then the *upper* pencil of 140° in oil is more than the *upper* 170° in air. If the 80° in glass below is in both figures equivalent, then the 80° above in oil is equal to the 170° above in air as regards light, and not different, as first alleged.

(*b*) Or the angular aperturist will contend that as the immersion objective is illuminated by the pencil of 140° in the slide, the dry objective must be so also.

First consider the object as not adhering to the slide (see Fig. 73).

Then he points out that the dry object is at a disadvantage because all of the illuminating pencil outside 82° cannot get out, but is reflected back at the top surface of the slide.

Fig. 73.



This is of course a wholly inconsistent argument. The point he started with was that it was the *balsam* mounting of the object that prevented the full aperture of the dry lens being utilized—the light getting *out*; now it is the *dry* mounting that is in fault, and that prevents the light getting *in*.

Dealing with the point in another way, the object *does* receive an illuminating pencil of 180°, for that is the extension of the pencil which emerges from the slide. If, according to the angular aperturist, 180° of emission in air is the whole emission, 180° of admission into air is the whole also. If he denies that because it is only 82° in glass, then he admits that an incident cone greater than 82° in glass is more than an incident cone of 180° in air; this admits the principle of the unequal equivalent of equal angles in regard to the rays *incident* upon an object, and there is then no ground for denying it in regard to the *emitted* cones.

Secondly consider the object as adhering to the slide.

Then the object may receive the whole illuminating pencil of 140°. What is the result as to emission, however?

If the object is *transparent* (with a plane surface) no more light than that equal to the reduced pencil of 82° can be emitted into air, whilst the whole 140° can be emitted into oil; the hemisphere of radiation in air contains, therefore, less light than the hemisphere in oil.

If the object is *structural*, the law of diffraction and Fraunhofer's formula show that every incident ray yields several deflected rays, and that in the hemisphere of air there are fewer deflected rays than there are in the hemisphere of oil, i. e. that the whole of the rays emitted into oil is greater than the whole emitted into air. Cf. Figs. 108 and 109.

(*c*) Finally, the angular aperturist says that all he meant to convey was that the cover-glass of the balsam-mounted object prevented rays of light passing out into air, while when a suitable immersion fluid is used they can pass out freely by reason of the critical angle having been abolished.

Of course the whole question between dry and immersion objectives depends upon the critical angle; and equally of course, both parties admit that the air above the cover-glass in Fig. 62 stops rays from reaching the objective. But the crucial question is, of what "*whole*" is a portion stopped off? The angular aperturist contended, a portion of *that* "whole" which is emitted in *air* when the object is uncovered. In fact, however, it is of *that* "whole" which is emitted in *balsam*, and as the balsam "whole" is much greater than the air "whole" (a fact which he denied), the fractional portion of the former which is emitted is not necessarily less than the "whole" of the latter.

By all methods, therefore, we come back to the demonstration of the essential fallacy of the angular aperturist, viz. that equal angles in different media are the same.

(3) Power of the Plane Surface of a Lens.—Another fallacy is that the plane surface of the front lens of an objective exercises power, so that when in a homogeneous-immersion lens the action of this plane surface is abolished by the use of the immersion fluid, the back spherical surfaces have to be increased in power by way of compensation. Or, to put it in another way, that in dry objectives the refraction at the plane surface atones for less refraction at the spherical!

This fallacy so continually crops up when diagrams are attempted to be drawn to illustrate the possibility of a dry lens equalling a wide-angled immersion lens in aperture, and in various other forms in discussions on the difference between the two kinds of objectives, that we think it will be useful to dispose of it once for all.

Dealing with *experiment* first, there is a very simple way of demonstrating the fallacy experimentally.

Take a homogeneous-immersion lens. Here the spherical surfaces are *supposed* to have been increased in power to replace the action of the plane surface which has been abolished by the immersion fluid. If, then, there was *loss* of power when the plane surface was *abolished*, there must be *gain* of power when the plane surface is *restored*. Restore the plane surface, therefore, by using the objective on a dry-mounted object. According to the view propounded, the objective must now magnify more than it did on the balsam-mounted object. Let any one who believes in it try the experiment and record the result!

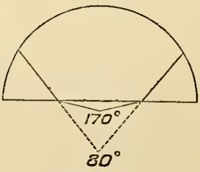
If *theory* is preferred to experiment, is it not obvious that a plane surface can have no power, the loss of which requires to be replaced by an increase of the power of the spherical surfaces?—that a plane surface is the optical zero as regards power (the hemisphere being the optical 1 or unit giving an amplification of an object at its centre in proportion only to the refractive index of the substance of which it is composed)? The refractive action of a plane surface affords change of divergence and of position of the focus, and in the case of wide-angled incident pencils introduces ample spherical aberration, but no power, so that the plane-front refraction can never be an element of power in a system, or compensate for loss of power anywhere else.

Again, as to the general dioptrical principle on which is based the distinction between "refraction with power," and "refraction without power." Amplification does not result from the unequal refraction of the rays coming from *one and the same object-point;* it depends solely on the unequal refraction of similar rays from *different object-points* (by similar rays being understood those which depart from different object-points in similar directions, i. e. parallel), and is therefore confined essentially to *curved* surfaces.

There may therefore be any large refraction of the *pencils* emitted from an object, but nevertheless no amplification, if parallel rays of any two different pencils should undergo the same refraction. This is the case of the plane surface. On the other hand, there may be no refraction of the *pencils* (the divergence of every pencil and the plane of the radiant may remain unchanged), but notwithstanding there may be any amount of amplification, provided parallel rays from two different object-points undergo unequal refraction. This is the case of a spherical surface in regard to an object situated at the plane of the centre of the sphere. Though in this case the divergence of the pencils and the plane of the focus is not changed by the refraction of the rays, there is an amplification of the object (as we have seen in the ratio of $1 : n$), because there is an unequal refraction of any two parallel rays from different points of the object.

Once more, what can the angle of the incident pencil have to do with power? If any lens or lens surface can refract a given pencil of, say, 82° to a conjugate focus with any given amplification (say, two diameters), the same lens, i. e. the same curvature in the same position, will bring any larger pencil (140°) to the same conjugate focus with the same amplification. No increase in the power of the spherical surface is required, but only greater diameter of the lens to admit the larger cone.

Fig. 74.



The front surface of a dry objective has, of course, the effect of reducing an incident pencil in air of 180° to a pencil of 82° in glass, but without contributing to the power of the objective. As is shown by Fig. 74, the *same pencil* which in air is emitted under an angle of 170° is emitted in oil under an angle of 80°, and thus does not require the reducing effect of a plane refracting surface, and therefore no compensation is necessary for the absence of such a refraction. The rays are in such case identical before they reach the spherical surface, which cannot therefore require any alteration.

(4) **The Diagram Fallacy** (*The Stokes Immersion and the Shadbolt Dry Objectives*).—The diagrams drawn by Mr. Shadbolt in support

of his contention that an immersion objective cannot have a larger aperture than a dry one, have, as is known, been frequently drawn before and their fallacy as often exposed, though, as the diagrams have been ultimately withdrawn by their authors, the exposition has not hitherto appeared in print. We now, however, give it.

Mr. Shadbolt's assumptions were as follows:—

He supposed a *homogeneous-immersion objective* with a front an exact hemisphere as suggested by Professor Stokes (see Fig. 75) which admits from Q a pencil of 113° balsam-angle and transmits it to the back combination as a pencil from q of 66°.

Fig. 75.

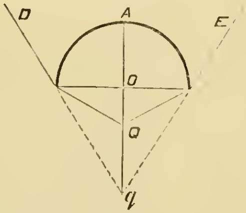
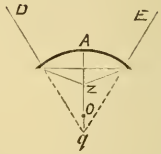


Fig. 76.



With this he compared a *dry objective* with a front lens of the same curvature as the immersion front, but of *less thickness* (as in Fig. 76). The position of the front in regard to the radiant was so arranged that a pencil from q of 66° is transmitted to the back combination as before. This pencil, however, emanates from a radiant z in air, and is of larger angle than the 113° which was the limit of the Stokes objective, so that it was supposed and contended that the latter had been changed into a dry objective of larger aperture! *

The application of one of the simplest and most elementary optical considerations shows at a glance that the demonstration is an entire mistake, and it well illustrates how deceptive geometrical diagrams of aperture may in reality be if they are drawn without a clear appreciation of the optical principles applicable to the subject.

There are two methods of demonstrating the fallacy, the one the *strict* and the other the *simple* method. We deal with the former first.

(a) *The Strict Method.*

With the same set of posterior lenses (of any given composition) the Stokes front would give an immersion objective of 112° 20′ crown-glass angle, and the Shadbolt front a dry objective of 125° 40′ air-angle under the conditions laid down in his paper, viz. that the emergent pencil with the virtual focus q is in both cases 66°.

Compare now the performance of these systems as to the ampli-

* The Shadbolt lens as it stands is not, of course, a practical construction, though the Stokes lens is. It could, however, be utilized by adding a duplex front to correct the spherical aberration. We have not done this, as it seemed that it might give rise to the supposition (though it would not be really the case) that we had altered the conditions laid down. We therefore simply note the fact.

fication which is obtained with them, beginning with the amplification of both fronts.

According to the law of aplanatic convergence referred to at page 321, if O and O* are any two conjugate aplanatic foci (it matters not whether O* is a real or a virtual focus), u and u^* the semi-angles of divergence of the pencils from these foci, N the linear amplification of the image at O*, and n and n^* the refractive indices of the medium in front and at the back of the system ; then

$$\frac{n \sin u}{n^* \sin u^*} = \mathrm{N}.$$

Applying this formula to the two front lenses, n^* is $= 1$ for both (there being air at the back), but n is $= 1 \cdot 525$ for the Stokes front, and $= 1$ for the Shadbolt front. Therefore, the linear amplification of the former (for the conjugate foci Q, q) is

$$\mathrm{N} = \frac{1 \cdot 525 \times \sin 56^\circ \, 10' \, (u)}{1 \times \sin 33^\circ \, 0' \, (u^*)} = (1 \cdot 525)^2 = 2 \cdot 33;$$

and of the latter (for the conjugate foci z, q)

$$\mathrm{N}' = \frac{1 \times \sin 62^\circ \, 50' \, (u)}{1 \times \sin 33^\circ \, 0' \, (u^*)} = 1 \cdot 63.$$

Let M be the linear amplification (whatever it may be) of the posterior system which is common to both objectives, then the total amplification of the Stokes objective (S) will be M.N, and of the Shadbolt objective (Sh) M.N′, which is less by $\frac{\mathrm{N}}{\mathrm{N}'} = 1 \cdot 42$, i. e. in the proportion of 5 : 7 approximately. Therefore, the focal length of the objective Sh must be greater than that of S in the same proportion, so that Sh is a *lower power with the same back combination.*

It has already been shown (p. 308) that, if a lower power objective utilizes only the *same* back lens as a higher power, it will not have the same, but a *lower aperture.* This must also be obvious instinctively, for if it were not so, opticians would of course make their $\frac{1}{4}$-inch of 120° aperture with the same *small* back lenses as are sufficient for the $\frac{1}{8}$-inch of 120° aperture !

Therefore, Mr. Shadbolt, claiming to have suggested a way to obtain the pencil from q with 66° divergence from air *without loss of aperture,* has in fact done so by a method which necessitates a loss of amplification, and therefore loss of aperture! In all cases of diagrams such as these, it is not sufficient to look only at the diagram on paper ; it is essential to put the question, "Have we still the same system ?"—i. e. the same power.

It may be said, however, that Mr. Shadbolt's suggestion was only given as an example, and that if it is insufficient another construction can certainly be devised for catching the pencil q with 66° angle from air, and without loss of aperture. Now, "without loss of aperture" can, under the conditions of the whole argument (the back combination remaining unaltered), mean nothing else than "without loss of amplification" in the action of the front. Therefore, if it is possible by any other means to catch the pencil *from air* without loss of aperture, a lens or any combination of lenses must exist which is capable of collecting rays from a focus Q in air to a focus q in air, so that the angle $u^* = 33°$, and the amplification N at $q = 2 \cdot 33$, as in the Stokes front. The above formula would then be

$$\frac{1 \times \sin u}{1 \times \sin 33° \,(u^*)} = 2 \cdot 33,$$

which would require an angle u for which

$$\sin u = 2 \cdot 33 \times 0 \cdot 545 = 1 \cdot 26,$$

that is, a sine greater than 1 !

The widest pencil which can be got out of a dry front under an amplification of $2 \cdot 33$ is defined by the condition

$$\frac{1 \times \sin 90°}{1 \times \sin u^*} = 2 \cdot 33, \text{ or } u^* = 25° \, 30', \text{ i. e. } 51° \text{ instead of } 66°.$$

Thus it is proved that the Stokes immersion-objective has a larger aperture than any dry objective with the same back combination can have. The same pencil (66°) which is readily got out of the immersion front into the back combination can*not* be got into it from *air*, except with loss of amplification, i. e. of aperture.

This disposes of the argument on the basis of Professor Stokes' diagram.

It does not prove, however, that *no* dry objective can have so large an aperture as can be got with an immersion lens ; it only proves that this is not possible with a dry objective under the assumption of the same back combination. On page 321 will be found the demonstration which proves that, as a *general proposition* applicable to all cases and apart from all questions of particular constructions, a dry (Shadbolt) objective can never equal in aperture an immersion (Stokes) objective of wide angle.

(b) *The Simple Method.*

But Mr. Shadbolt may say that his mistake must have been a very excusable one if the proof requires formulæ which are not to be found in English books, and we will therefore show how by the application of the most elementary principle to be found in English optical books, and without any calculation, the fallacy may be demonstrated.

The loss of amplification with the Shadbolt front is obvious at a glance, for the refraction at the spherical surface has been *diminished.*

A spherical surface (of refractive index n) amplifies an object which is within the medium (for instance, the *virtual* object obtained from the *real* object below a plane front surface) according as the distance of such object from the vertex is increased. If the radiant coincides with the centre the linear amplification will have a given value ; † but if the radiant is withdrawn from the centre to a point more distant from the vertex the radiant of the emergent pencil is withdrawn still more. The emergent pencil is reduced in divergence and, all other circumstances remaining the same, this necessarily indicates *increased* amplification.

† It will in fact be n, see *ante*, p. 327.

Thus *withdrawing* the radiant from the vertex of the sphere is *increase* of amplification by the spherical surface, and *approaching* the radiant is *loss* of amplification—propositions the truth of which may be very readily tested by an ordinary plano-convex lens.

Now in the Shadbolt front *the radiant has been brought nearer to the vertex!* and there is therefore loss of amplification (cf. Figs. 75 and 76).

This approximation is moreover a necessity, for Mr. Shadbolt so far rightly saw that his emergent pencil of 66° could not be so much increased within the glass as it is in the Stokes front. In the latter (considering the pencil from above downwards) the 66° can be increased to 113° as there is no plane surface of exit bounded by air. In the dry objective, however, there is such a surface, and nothing beyond 82° can emerge, so that instead of being able to increase the pencil from 66° to 113° it can only be increased to 82°, that is, the refraction at the spherical surface must be diminished in order to have within the glass a pencil not exceeding 82°.

The notion that the refraction which is introduced by the lens at the plane front surface can compensate for this loss at the spherical, is one of the strangest of the aperture fallacies, as has been shown in the preceding note.

In this simple mode the fundamental mistake of Mr. Shadbolt's diagram is shown.

(5) **Fallacies in Practical Construction.**—It need hardly be pointed out that the better practical optician will, *cæteris paribus*, be he who is the best grounded in those theoretical principles which lie at the root of the construction of objectives. The mistakes into which the practical optician who is an angular aperturist is led, may be shown by several instances:

(1) We will take first the case of the construction of objectives of high angles. An optician holding the views we have referred to, will have observed that when he increased the angular aperture of his objective from 100° to 120° he obtained a substantially increased effect. He is therefore encouraged to improve the construction and add yet another 20°, making 140°, or a third 20°, making 160°, and yet more until he arrives at the nearest approximation to 180°, all the time supposing that with each additional 20° he had obtained the same increase of effect as at first.

The knowledge that aperture must be measured by the *sines* and not by the *degrees* would, however, have shown him that the increasing effect was not properly indicated by the figures 100, 120, 140, 160, and 180, but by 77, 87, 94, 99, and 100; so that the real increase is not by additions of 20, but of 10, 7, 5, and 1 only. He would see, therefore, that the difference between 140° and 180° was so slight—being only 6 per cent.—as not to make it worth his while to encounter the difficulties of technical construction attendant upon the extreme increase of angle.

(2) If the practical optician considers that *aperture* and *angle* are identical, the same angle being always the same aperture whether in a dry or an immersion objective, he will continue to struggle for the optical *perpetuum mobile*—to construct dry systems which shall equal

in performance the best immersion glasses, which would undoubtedly be a great triumph, inasmuch as dry objectives are so much more convenient to use than immersion. Why should not this be possible, he thinks, with skill and patience, if the question depends simply on the angle of the admitted pencil!

(3) If, again, he should hold one of the views of the effect of increased angle which we have above referred to (p. 319), viz. that it is a defect, he will confine himself to the construction of objectives of low angle, which he contends must in all cases exhibit objects better than those of large angle. With the large angle there is greater all-round vision, as if many eyes were looking at the object at the same time, and hence the resultant effect must, he thinks, be general indistinctness and imperfection in the image. Yet objectives of the highest angles hitherto constructed are easily proved to give images of sufficiently thin preparations without confusion.

(4) Several other practical mistakes flow from the same erroneous theoretical assumptions, one of the most important of which we deal with under a separate head, "Not Image-forming Rays."

(6) "Not Image-forming Rays."—This represents a very curious form of the angular fallacy.

At the commencement of the old aperture controversy, it was asserted that no objective could be constructed, whether dry or immersion, which would allow of an angle in excess of 82° in the body of the front lens. In the same way as Nature abhorred a vacuum, she was supposed to abhor an objective which could act in such defiance of established laws of critical angles and otherwise!

At the time that this view was first enunciated, no such objectives had in fact been constructed, so that the statement was then partially excusable. The first claim to have constructed such an objective was received with great derision, and it required some years to finally establish what is, however, *now* universally accepted as a fact, that immersion objectives *do* allow of an angle in excess of 82° in the front lens.

The germ of the original fallacy still persists, however, in the contention that although the surplus rays in excess of the 82° do really exist, yet that they are *not image-forming rays*.

Now as the limit of 82° is simply double the critical angle between *air* and glass, it can have no possible application whatever to the case of rays passing, not from air, but from *water* or *oil* to glass, and it must be clear therefore on theory that this notion is a fallacy.

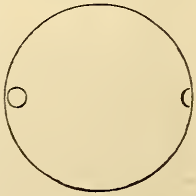
It is obviously for those who contend that the rays (even when passing from oil to glass, and without any air-film!) cease to be image-forming rays at 82°, to show on what grounds they base their contention; but we will nevertheless point out one or two experiments which—apart from any reference to the obvious theoretical considerations—show the *effective* action of the surplus marginal rays with wide-angled immersion objectives. It is hardly necessary to point out that for these experiments it is essential to use objectives which are properly corrected for *all* zones, marginal as well as central. There are plenty of such objectives in existence, though it is not unnatural that the belief that the surplus rays passing through the marginal zones are not image-forming rays, should lead the optician to concentrate his attention on the central corrections to the comparative neglect of the marginal. Any experiments with *such* objectives will, of course, be useless.

The simplest experiment of all is to take a homogeneous-immersion objective of large aperture, say 1·25, and put a stop (of cardboard or tin-foil) on the back lens, leaving only a small clear annulus of the extreme marginal rays. With sufficient obliquity of the illumination the image of the object will be seen perfectly delineated either on a dark or bright field.

Another experiment is to take a similar objective and focus it to any rather coarse object with sharp outlines (say lines ruled in a thin silver film on a cover-glass and balsam mounting) and illuminate by a narrow pencil from an immersion condenser such as a hemisphere, so as to be able to get at pleasure a very oblique pencil. If the illumination is changed from central to very oblique until the field begins to darken, a well-defined image of the outlines will be seen with slightly coloured borders only. If the illuminating apparatus admits of a rapid change of the incidence without any alteration of the object, it can be established that the image with the oblique beam is obtained at *the same focus* of the eye-piece, and that no change of adjustment is required for distinct vision. Looking down the tube when the eye-piece is removed, the oblique pencil will be seen emerging close to the margin of the clear aperture of the objective. Thus the marginal zone transmits image-forming rays.

Or focus the objective on a good specimen of *Amphipleura pellucida* and use sufficiently oblique illumination for seeing the lines clearly. On removing the eye-piece, placing the pupil on the air-image of the diatom and looking down on the lens, the direct incident beam will be seen emerging as a bright spot and exactly opposite and *close to the margin* a faint bluish light (a portion of the first spectral beam) —see Fig. 77. If now a small piece of paper is placed on the back lens of the objective so as to just cover up the blue light, and the eye-piece is replaced, the diatom is still visible, but all the striation which was imaged by the blue marginal light has entirely disappeared. The latter must therefore consist of image-forming rays.

FIG. 77.



Other instances may be shown by using the vertical illuminator, in the manner suggested by Mr. Stephenson,* in which case, when transparent objects are used, the light within 82° passes through, and is not brought to the eye. The image is therefore seen by the marginal rays.

Indeed, the experiments which show the absurdity of the notion

* See this Journal, ii. (1879) p. 266.

that the marginal rays are not image-forming may be almost infinitely varied.

If these experiments cannot be made to bring out the desired results, one thing is evident, the objectives that have been made use of have not been properly corrected!

(7) **"Only a Question of Nomenclature."**—The last fallacy of the angular aperturist, after he feels that his view is not so sound as he supposed, is that the dispute has been "only a question of nomenclature."

Now we quite agree that in scientific discussions generosity to fallen foes is no more out of place than it is in actual warfare, but, nevertheless, we have always combatted this remark, because we have had impressed upon us by the force of considerable practical experience that it has in the past largely contributed to obscure the fact, which it is essential should be borne in mind, that the difference in the two views is in reality one of the highest importance, and one which every person who works with the Microscope should appreciate. The biologist and even the microscopist sees the controversy on aperture end in the suggestion that it is "only a question of nomenclature," and he therefore comes to the conclusion that the whole matter is one of perfect indifference as regards the practical use and improvement of the Microscope. If English microscopists had only been able to grasp the theoretical grounds on which wide-angled immersion lenses are shown to have necessarily a larger aperture than dry ones, there can be no doubt that we in England would have been ten years ago where we are only to-day.

"Only a question of nomenclature" is a phrase which has a well-defined meaning, being applied to the case of discussions in which there is agreement as to the *essence* of the thing which forms the subject of discussion, the difference being only as to what it should be *called*.

Let us consider then whether the differences on which the aperture theories are founded do or do not go to the essence of the matter, and in this we will draw exclusively from the printed pages of the recent discussion. We confine ourselves to a few only, but we need hardly point out that an exhaustive consideration would of course simply be a summary of the whole of the fallacies to the exposure of which the preceding pages have been devoted.

(1) It was asserted and made the keystone of the demonstration that the radiation of light in air was exactly the same as radiation in water or oil, and that equal angles in different media represented equal apertures. If that is only a question of nomenclature there can never be a dispute on essentials.

(2) To support the view contended for, it is supposed that the plane surface of a lens exercises power, and that when that is abolished there is a loss, which must be compensated for by increased curvature at the spherical surfaces. This is a notion which not only upsets all the principles of practical optical construction, but the most settled—indeed, the simplest—laws of optics. Can it be said that this is only a dispute over nomenclature?

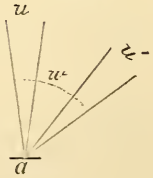
(3) *A dry objective of* 180° *angle, working on dry objects, is assumed to represent the maximum of microscopical perfection as regards aperture which can never therefore be surpassed by an immersion objective.*

Will any one seriously maintain that a dispute on *this* point is only one of nomenclature—that it is only a question of nomenclature to contend that immersion objectives present only incidental and comparatively unimportant advantages over dry objectives, except in the single case of the latter being used on balsam-mounted objects, and to deny to them the quality which raises them, in regard to aperture, above anything to which the most perfect dry objective can ever attain? a quality, moreover, which is not a merely abstract optical consideration, but is in fact an essentially *practical* one in regard to the performance of the Microscope upon the most minute objects.

III. Photometrical Questions connected with Aperture.

(1) Difference of Radiation in the same Medium. — The Lambert law shows that the quantity of light emitted by any infinitesimal surface-element (or "bright point") varies with the obliquity of the direction of emission, being greater in a perpendicular than in an oblique direction. The rays are less intense in proportion as they are more inclined to the surface which emits them.

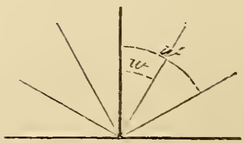
Fig. 78.



If a (Fig. 78) is a radiant element emitting light within a small cone u (of angle q) in a perpendicular direction, and also within an *equal* cone u' in an oblique direction, the angle of obliquity between the two being w, then the quantity of light emitted by the element a in the oblique direction, and contained within the cone u', is *less* than that which it emits in the perpendicular direction and contained within the cone u, though the cones are of equal extent (q). The relative quantities of light in the two cones are as $q : q \cos w$; so that a pencil varies according as it is taken close to or removed from the perpendicular.

Owing to the different emission in different directions, therefore, the quantities of light emitted by one and the same element in one and the same medium, by cones of *different* angle (w and w', Fig. 79) are *not* in the ratio of the solid cones, as would be the case with equal emission in all directions, but in the ratios of the squares of the sines; so that the squares of the sines of the semi-angles constitute the true measure of any solid pencil of rays.

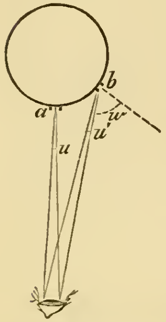
Fig. 79.



The simplest experimental proof of the unequal emission in different directions will be found in the fact that the sun, or the moon, or any similar bright spherical object, with so-called uniform radiation in all directions, is seen projected as a surface of *equal* brightness.

If there were equal intensity of emission in all directions, what would be the necessary result? Compare two equal portions of the surface, one a (Fig. 80) perpendicular to the line of vision, and the other b greatly inclined. Every infinitesimal surface-element of b sends to the pupil of the eye a cone of the same angle u' as a similar point of a (the slight difference of the distance from the eye being disregarded). If the intensity of the rays were equal, as supposed, the whole area b would send to the eye the *same* quantity of light as the equal area a, since both areas contain exactly the same number of elements. But the *whole* quantity of light from b would be projected upon a smaller area of the retina than that from a (as b appears under a smaller visual angle, being diminished according to the obliquity, or as $1 : \cos w$). Consequently, if the assumption were true, b must appear to be brighter than a, and the sphere would show increasing brightness from the centre to the circumference. Close to the margin the increase ought to be very rapid, and the brightness a large multiple of that at the centre.

Fig. 80.



This, as is well known, is not the case—the projection of the sphere showing equal brightness. The quantity of light, therefore, emitted from b within a given small solid cone u' in an oblique direction, must be *less* than that which is emitted from a within an equal solid cone u in a perpendicular direction; and the intensity of the rays must decrease in the proportion of $1 : \cos w$ when the obliquity w increases.

Therefore Fig. 81 is not a correct diagram of the rays emanating

Fig. 81.

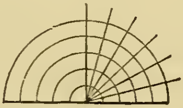
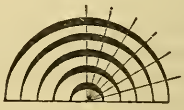


Fig. 82.



from a surface-element, but Fig. 82—the density of the rays decreasing continuously from the vertical.* (Cf. also Figs. 59 and 60.)

This subject bears also upon the question of the loss of light with dry objectives. It was seen that immersion objectives gave a great increase of light over dry objectives. As the true explanation of this was not appreciated, it became necessary to account for the increase otherwise, and the reflection at the plane face of the lens was taken to be the reason. A large amount of loss is supposed to be accounted for by the following reasoning:—A pencil of light is assumed to be properly shown in Fig. 81, the density of the rays being uniform, whether they are close to or removed from the perpendicular. If this pencil

* The thickened lines indicate the greater amplitudes.

is supposed to be divided into, say, three equal parts around the perpendicular, the loss of light by reflection in the second third, where the rays are more oblique than in the central one, is assumed to be much greater than in the latter, and the loss in the outer third, where the rays are yet more oblique, as much greater still; so that a total average loss is made out to exist of not far short of 50 per cent.

The consideration is so far sound in that it proceeds on the assumption that the loss of light by reflection increases with the increasing obliquity of the rays. The mistake, however, is in supposing that Fig. 81 is a correct representation of the pencils instead of Fig. 82. In the calculation of the 50 per cent., therefore, the fact was overlooked that while with increasing obliquity there is greater loss by reflection, yet there is at the same time *less light to lose.*

There is of course loss of light with a dry front, which is nearly all avoided in the case of the immersion, and is so far a practical benefit. This benefit, however, is very subordinate in comparison with the great increase of light which is due to the greater photometrical equivalent of equal cones in denser media, an immersion objective of 120° balsam-angle being capable of admitting more light in the ratio of 9 : 4 than a dry lens of equal air-angle.

(2) **Increase of Radiation in Glass, Oil, &c.**—The angular-aperture theory, as we have already seen, is sometimes rested (though improperly) entirely upon the question of quantity of light, and involving the assumption that equal angles in air and balsam contain the same amount, so that a smaller angle in balsam must contain less than a larger air-angle. The notion that a balsam-angle of 100° can contain more light than an air-angle of 180°, a given fixed illumination being supposed, is regarded as an absurdity.

The fact of an increase in radiation with the increase in the refractive index of the medium into which the emission takes place has been established for many years, the case of immersion objectives being hitherto the main (if not the first) practical application of it. The principle may be proved theoretically and experimentally.

Those who are interested in the *theoretical* consideration will find it fully developed by Professor R. Clausius in his celebrated paper "On the Concentration of Calorific and Luminous Rays." * Later, a similar principle was shown by Professor Helmholtz (in his paper "On the Limits of the Power of the Microscope") to be a direct deduction from that of conservation of energy. The former paper was an outcome of researches which were induced by previous researches of Sir W. Thomson and Professor Rankine.

For the *experimental* consideration, the apparatus which we exhibited at the March meeting, and for which we are indebted to Professor Abbe, will be found useful for showing the different *photometrical* equivalent of equal angles in different media.

The apparatus (see Figs. 83, 84, 85) consists of a very thin plate of polished porcelain A, which (for support) is cemented with balsam to a disk of ordinary glass *a*. A block of crown glass G is also cemented with balsam to the polished surface of the plate A. A

* Poggendorff's Annalen, cxxi. (1864).

second plate B b, exactly similar to A a, is laid on the anterior surface of the glass block G. The whole is mounted in a brass box, for convenient manipulation, and for limiting a given portion f_2 of the anterior porcelain plate A, exactly equal in size to the sectional

Fig. 83.

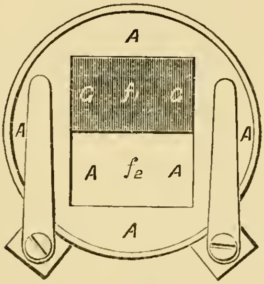


Fig. 84.

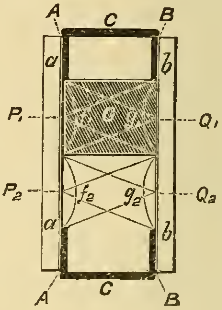
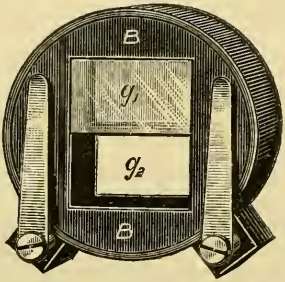


Fig. 85.



surface f_1 of the glass block. The plates A and B are ground down to such a thinness that they are just non-transparent for *direct* rays, but give a strong *diffused* illumination, radiating very uniformly in all directions.

If now the apparatus is directed to the sky, or held close to a gas-flame (the plate B being turned towards the observer and shaded from any incident light*), *one* of the fields g_1 or g_2, opposite to f_1 or f_2, will appear *decidedly and considerably brighter* than the other.

At the March meeting this fact was at once triumphantly accounted for by an angular aperturist. "The light passing through "the air space is unimpeded and unabsorbed, and therefore illuminates "that part of the plate B which is opposite to it more strongly. In "passing through the glass block, however, it is absorbed, and so "shows a feebler illumination." On removing the plate B, however, it was seen that it was the field g_2 opposite to f_2, and with the *air-space* intervening, that had the *feebler* illumination, as if the light had passed through a fog; whilst f_1, where the light had passed through the glass block, gave the greater illumination!

What does this experiment show? As the two fields, f_1 and f_2

* In Fig. 85 both of the plates A and B are supposed to be removed.

of the plate A are close to one another and are of equal size, the same quantity of light (very approximately) will be incident upon them; and as the plate A is of porcelain and polished, neither the internal constitution nor the surface undergoes any change by the cement connecting it with the glass block. Thus the two fields f_1 and f_2 are under equal conditions, with the difference, however, that f_1 emits rays into balsam and crown glass, and f_2 into air.

The plate B, which is only laid on the glass block, receives all the light which has been emitted *into balsam* from f_1 upon the opposite surface g_1 of the glass block, and all which has been emitted from f_2 *into air* and upon the field g_2. As the former field is brighter than the latter, the quantity of light emitted in the one case must necessarily be greater than in the other, and the more so since the absorption of light is certainly greater in the glass block.

Owing to the identity of all geometrical conditions, it is obvious that every point P_1 of the surface f_1 throws upon the field g_1 the same solid cone of rays as the corresponding point P_2 of f_2 throws on g_2, and that every point Q_1 of the field g_1 *receives* an equal cone to the corresponding point Q_2 of the field g_2. Consequently, the intensity of emission in balsam must be greater than the intensity of emission in air, whilst the illumination of the object and all other circumstances are the same. A similar difference of emission must take place in all directions round the points P_1 and P_2; and thus the whole of the emission in balsam (i. e. the quantity of light conveyed from every unit of surface within the whole hemisphere) is seen to be greater than the whole in air, a given fixed illumination being supposed.†

The idea of an unequal photometrical equivalent of equal pencils in different media may be developed by some simple experiments, which also show how absurd is the notion that there is a loss of aperture (or of light apart from mere partial reflection) when a dry objective is applied to a balsam-mounted object.

(1) Any object O in air (Fig. 86) will send into the pupil a pencil of a given angle u^* from every point, and is seen (with any given fixed illumination) with a certain brightness.‡

† This does not, of course, imply the assertion that the *whole* of emission from such a porcelain plate, or any other object with diffused radiation, would *increase continually* as the refractive index of the surrounding medium is increased, which would lead to the absurd inference that such an object could give out more light than is incident upon it! If the index of the medium should exceed the refractive index of the object, the radiation (whether of reflected or transmitted light) no longer embraces the whole hemisphere, but breaks off at a given obliquity. This is shown from the consideration that the emission of light is not confined to the mathematical surface of the object, but arises from a layer of finite (though very small) depth. Thus, the *total* amount of reflected or transmitted rays from an object reaches a maximum with a given density of the surrounding medium, though the emission within any narrow cone (as long as there *is* emission still) will always increase with increasing density.

‡ If the distance is increased and the angle u^* diminished, the *area* of the retina which is affected by the rays from a given area of the object is of course diminished as the square of the distance, i. e. in the same ratio as the number of the rays from every point is diminished. Every sq. mm. of the retina receives, therefore, the same quantity of light at all distances, and the object, therefore, always appears of the same *brightness*.

(2) An identical object O (Fig. 87) *cemented to the under surface of a glass plate*, will appear at a somewhat higher plane O*, but neither amplified nor reduced. The pencil u, however, which is gathered in from the radiating object, is less in angle than u^* in the ratio approximately of $1 : 1 \cdot 5$; and if, therefore, equal pencils in air and in glass were equivalent the quantity of light emitted from any square millimetre of the object and received by the pupil would be less in the proportion of $1 : (1 \cdot 5)^2 = 1 : 2 \cdot 25$. The object would therefore be seen *less bright* in the same proportion.

FIG. 87.

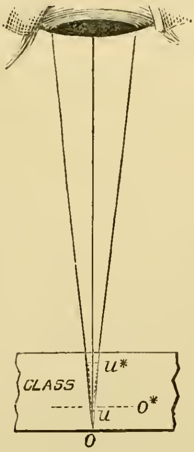


FIG. 86.

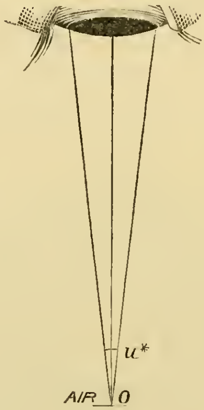
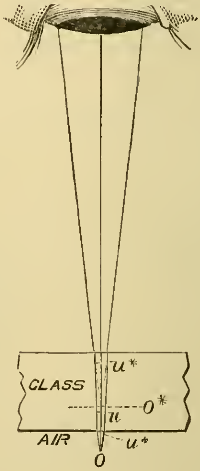


FIG. 88.



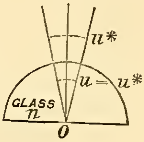
(3) The same object, separated by air from the under surface of the plate, would emit once more pencils of the aperture u^* (Fig. 88). The circumstances will be the same as in (86). As the loss of light at a polished glass surface with perpendicular incidence is not more than about 6–7 per cent., this case, 88 (if the hypothesis were correct) would show the object *brighter* than (87) at least in the proportion of 2 : 1. Any one may satisfy himself at once that this is *not* the case, and that the difference in brightness between (88) and (87) is not appreciable. Therefore the smaller pencil u *in glass* must contain as much light as the wider pencil u^* *in air*.

If instead of the eye a microscope objective (dry) which takes in any wide pencil—say 140°—is used, the above considerations must equally apply; if $u^* = 140°, u = 2 \times 38° 50' = 77° 40'$ (n being $1 \cdot 5$). The second case (87) would be that of an object cemented to the under surface of the covering-glass. The third case (88) would be that of an identical object with the cover-glass laid on only. If 140° in glass were the same as 140° in air, the 77° 40′ in glass would be very much less, and as the quantities of light must be estimated by the squares of the sines, there would of course result a *very great difference* of brightness in passing from (87) to (88), so great that at any rate it cannot be accounted for by the loss of light from *one* reflecting surface *more.*

The experiments must of course be made with illumination from *below* in order to secure equal illumination in the three cases, and with objects which are not altered by immersion in balsam or oil.

More striking still is the result of the following consideration. Suppose an exact hemisphere of glass ($n = 1 \cdot 5$) and an object close to its centre and under the conditions of (87) (Fig. 89).

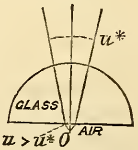
FIG. 89.



The object adhering to the glass is seen by the naked eye or by a Microscope at the same plane at which it actually is, and with the *same brightness* as when in air (see Fig. 86) (the slight loss by absorption and reflection not considered). It is, however, amplified in the ratio of $1 : n$.

Apart from any consideration of the *cause* of this amplification, the question necessarily arises, how is it possible that *equal* pencils (i. e. of the same angle), the one in air (86) and the other in glass (89), give the same brightness while in air (86) every square millimetre of the object continues to be the same square millimetre, and in (89) every square millimetre of the object is *enlarged* to $n^2 \times$ sq. mm. The total quantity of light which is obtained from every square millimetre of the object is obviously n^2 times *more* in (89) than in (86). There can be no other answer than this: pencils of equal angle, the one emitted in air and the other in glass, are *different* things *physically*, though they are *equal geometrically*—the pencil in glass contains $n^2 \times$ the light of the pencil in air. This conclusion is shown to be correct by comparing (89) with Fig. 90, where the object is in air but close to the plane surface (as in 88). Here the pencil from the object, in order to yield the same emergent pencil u^*, must have an angle u in air, which is greater than u in (89) according to the law of refraction. Nevertheless this greater cone of the emitted rays brings out the same brightness of image as in (89) under the same amplification.

FIG. 90.



IV. Microscopical Vision and the Delineating Power of Objectives.

The consideration of aperture involves two distinct questions: *First,* Can immersion objectives have any and what excess of aperture over the maximum attainable by dry objectives? and *secondly,* What is the function of increased aperture?

Up to this point we have been occupied exclusively with the first question (to which, in accordance with the practice hitherto in vogue, we have given priority) the angular aperture theory insisting that a dry objective of 180° air-angle represents the maximum aperture possible. The mistake of this view and the establishment of the true view may, as it has been seen, be demonstrated upon those ordinary dioptrical principles, with none of which can, or in fact does, the angular aperturist venture to disagree. His mistake has not been based on any ignorance of those principles, but has simply arisen from a deep-rooted disinclination to modify former views—a disinclination which, not for the first time in the history of science, has led those who are beset by it to deny the plainest facts long after their truth has been established.

Leaving now the consideration of the increased aperture of wide-angled immersion objectives over dry objectives, we propose to deal with the second question (which represents a problem that long perplexed the minds of microscopists), *On what principle does the advantage derived from increased aperture depend?* That an increase in the aperture of objectives is accompanied by an increase in their performance has been established since the date of Dr. Goring's discovery of the fact, and the true explanation, whatever it may be, is of course independent of any consideration of apertures in excess of 180° angular in air or even of immersion objectives at all. The question arises when we consider only *dry* objectives.

Down to so late as 1870 all endeavours to give an answer to this question had entirely failed. One of the ablest and most elaborate of these attempts is that contained in the article "Angular Aperture" in the 'Micrographic Dictionary,' but apart from the fact that it starts with the fallacious assumption that the essential condition of increased aperture is increased obliquity of the rays to the object, no one can ever have risen from a perusal of that article, who was really desirous of understanding the subject, without feeling the unsatisfying character of the explanation attempted. That the true explanation was still wanting was evident from the remarkable way in which all microscopical authors avoided the subject, never getting beyond the bare statement of fact that increased aperture in some way involves increased resolving power. More than one microscopist devoted great pains and labour to the endeavour to establish a consistent theory, but all failed in consequence of having continued to consider microscopical vision as essentially the same in principle as vision with the naked eye, and so applying to the question only *dioptrical* considerations.

The crucial question which any explanation of the virtue of increased aperture must face is the following, which on the old view must necessarily be an insoluble paradox. How is it that we obtain a greater effect by the increased obliquity of the incident illuminating beam *to the axis of the Microscope*, even although at the same time its obliquity *to the object* is decreased? The ordinary explanation of shadow and similar effects obviously fails here.

(1) The Abbe Theory of Microscopical Vision.

The solution of all the mystery was at last discovered by approaching the matter from a different point of view, and recognizing what is now obvious, that in the case of the objects of minute size with which the Microscope deals, and for the vision of which aperture is necessary, the conditions of ordinary vision do not apply.

When we consider waves of sound it is a well-recognized fact that to produce an acoustic shadow the obstacle must be many times greater than the length of the sound-waves. If the obstacle is reduced in size the waves pass completely round it, and there is no shadow, or if the notes are of higher pitch so that the waves are reduced in size a smaller obstacle than before will produce the shadow. In the case of light, when the objects are large in comparison with the wave-lengths, shadow effects, of course, result, that is, we have a rectilinear propagation of the light; but when they are reduced to smaller and smaller dimensions they are not now many multiples but only a few multiples of the wave-lengths, and we have no longer rectilinear propagation,—*dioptrical* considerations are not therefore applicable, and we have to refer to the laws of *diffraction*, i. e. those laws which explain the changes produced in the rays of light in consequence of their interception or unequal retardation by minute particles. In now explaining microscopical vision, it is necessary, therefore, to take into account that the images of objects in the Microscope are not formed, as was formerly supposed, exclusively on the ordinary dioptric method (that is, in the same way in which they are formed in the camera or telescope), but that the microscopical image is very largely affected by the peculiar manner in which the *minute* constitution of the object gives rise to the phenomena of diffraction.

It is hardly necessary to say that Professor Abbe's discovery constituted a most important innovation upon the views formerly current (as much so as the spectroscope and the telephone in chemistry and physics). The honour of the discovery belongs to him alone, no hint of it having been previously given, and no one having even seen what every one can now easily see, a "diffraction spectrum" in the Microscope.

(a) *Minute Objects.*

The phenomenon of diffraction in general may be observed experimentally, as is well known, by plates of glass ruled with fine lines. Fig. 91 shows the appearance presented by a single candle-flame seen

Fig. 91.

through such a plate, an uncoloured image of the flame occupying the centre, flanked on either side by a row of coloured spectra of the flame, which grow dimmer as they recede from the centre. A similar phenomenon may also be produced by dust scattered over a glass plate, and by other objects whose structure contains very minute particles, the light suffering a characteristic change in passing through such objects, that change consisting in the breaking up of a parallel beam of light into a group of rays, diverging with wide angle, and forming a regular series of maxima and minima of intensity of light, due to difference of phase of vibration. The formula in which these phenomena are expressed is that known as Fraunhofer's formula, which was first published in 1821.*

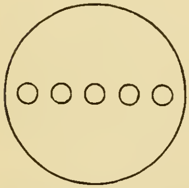
* Denkschr. k. Bayer. Akad., viii.

Dealing now with the phenomena of diffraction as more immediately connected with microscopical vision, the existence and influence of the diffraction spectra in the Microscope may be demonstrated theoretically and experimentally. The theoretical demonstration has been given by Professor Abbe in his original paper,* and a simple and intelligible exposition will also be found in Naegeli and Schwendener's 'Das Mikroskop.' †

The point which is of importance for our present purpose in Abbe's researches is that Fraunhofer's formula was for the first time applied to microscopical vision, and the influence of the diffracted light on the image investigated.

If a diaphragm-opening be interposed between the mirror and a plate of ruled lines placed upon the stage, the appearance shown in Fig. 92 will be observed at the back of the objective on removing the eye-piece and looking down the tube of the Microscope. The central circle is an image of the diaphragm-opening produced by the direct, so-called non-diffracted, rays, while those on either side are the diffraction images produced by the rays which are bent off from the incident pencil. In homogeneous light the central and lateral images agree in size and form, but in white light, as might have been expected, the diffracted images are radially drawn out, with the outer edges red and the inner blue (the reverse of the ordinary spectrum), forming, in fact, regular spectra, the distance separating each of which varies inversely as the closeness of the lines, being, for instance, with the same objective twice as far apart when the lines are twice as close.

Fig. 92.



The formation of the microscopical image is explained by the fact that the rays collected at the back of the objective, depicting there the direct and spectral images of the source of light, reach in their further course the plane which is conjugate to the object and give rise there to an interference phenomenon (owing to the connections of the undulations), this interference effect giving the ultimate image which is observed by the eye-piece, and which therefore depends essentially on the number and distribution of the diffracted beams which enter the objective.

That the diffraction spectra are not mere superfluous and accidental phenomena but are in fact directly connected with the image seen by the eye, has been very fully demonstrated by Professor Abbe at a special meeting held for the purpose, and recorded in our Proceedings in the Journal, as well as in papers by Mr. Stephenson before this Society, by Dr. Fripp before the Bristol Naturalists' Society, and by ourselves before the Quekett Microscopical Club. These papers are printed at full length in the Proceedings of the respective Societies, with the illustrations used, so that we may

* See references collected in this Journal, ii. (1879) p. 651.

† 2nd ed. (1877), English Translation (1881), p. 233.

confine ourselves here to a few only out of the numerous cases in which the special influence of the diffraction spectra may be demonstrated.

The first experiment shows that with, for instance, the central beam, or any one of the spectral beams alone, only the contour of the object is seen, the addition of at least one diffraction spectrum being essential to the visibility of the structure.

Fig. 93 shows the appearance presented by an object composed of wide and narrow lines ruled on glass, when viewed in the ordinary

Fig. 93.

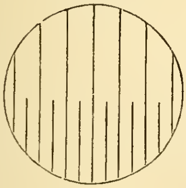
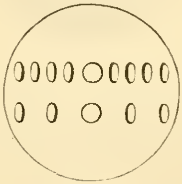


Fig. 94.

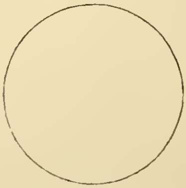


way with the eye-piece in place, and Fig. 94 the appearance presented at the back of the objective, when the eye-piece is removed, the spectra being ranged on either side of the central (white) image, and at right angles to the direction of the lines; in accordance with theory, they are farther apart for the fine lines than for the wide ones.

If now, by a diaphragm at the back of the objective, like Fig. 95, we cover up all the diffraction spectra, allowing only the direct rays to reach the image, the object will appear to be wholly deprived of

Fig. 95.

Fig. 96.



fine details, only the outline remaining and every delineation of minute structure disappearing just as if the Microscope had suddenly lost its optical power, see Fig. 96.

This illustrates a case of the *obliteration* of structure by obstructing the passage of the diffraction spectra to the eye-piece.

The second experiment shows how the appearance of fine structure may be *created* by manipulating the spectra.

If a diaphragm such as that shown in Fig. 97 is placed at the back of the objective, so as to cut off each alternate one of the upper row of spectra in Fig. 93, that row will obviously become identical with the lower one, and if the theory holds good, we should find the image of the upper lines identical with that of the lower. On replacing

Fig. 97.

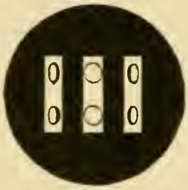
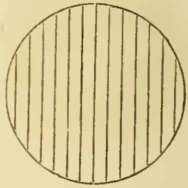


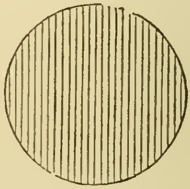
Fig. 98.



the eye-piece we see that it is so, the upper set of lines are doubled in number, a new line appearing in the centre of the space between each of the old (upper) ones, and upper and lower set having become to all appearance identical (Fig. 98).

Fig. 99.

Fig. 100.



In the same way, if we stop off all but the outer spectra as in Fig. 99, the lines are apparently again doubled, and are seen as in Fig. 100.

Fig. 101.

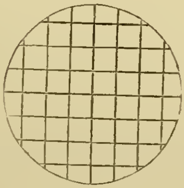
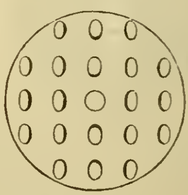


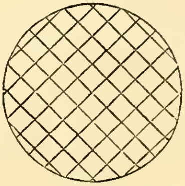
Fig. 102.



A case of apparent creation of structure similar in principle to the foregoing, though more striking, is afforded by a network of squares such as Fig. 101, having sides *parallel* to this page, which gives the spectra shown in Fig. 102, consisting of vertical rows for the horizontal lines and horizontal rows for the vertical ones. But it is readily seen that two diagonal rows of spectra exist at right angles to the two diagonals of the squares, just as would arise from sets of lines in the direction of the diagonals, so that if the theory holds good we ought to find, on obstructing all the other spectra and allowing

Fig. 103.

Fig. 104.



only the diagonal ones to pass to the eye-piece, that the vertical and horizontal lines have disappeared, and two new sets of lines at *right angles to the diagonals* in their place.

On inserting the diaphragm, Fig. 103, and replacing the eye-piece, we find, in the place of the old network, the one shown in Fig. 104, the squares being, however, smaller in the proportion of $1 : \sqrt{2}$, as they should be in exact accordance with theory.

An object such as *Pleurosigma angulatum*, which gives six diffraction spectra arranged as in Fig. 105, should according to theory show markings in a hexagonal arrangement. For there will be one set of lines at right angles to $b\ a\ e$, another set at right angles to $c\ a\ f$, and a third at right angles to $g\ a\ d$. These three sets of lines will obviously produce the appearance of fields arranged as shown in Fig. 106. The exact shape of the bright spot of every field is shown by theory to be *circular*, which is readily verified by observation.

Fig. 105.

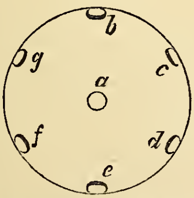
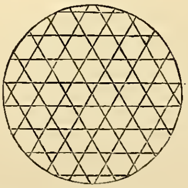


Fig. 106.



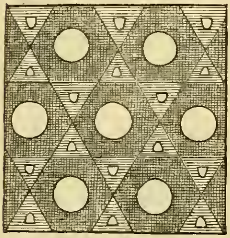
A great variety of other appearances may be produced with this same arrangement of spectra. Any two adjacent spectra with the central beam (as $b\ c\ a$), will form equilateral triangles, and give hexagonal markings. Or by stopping off all but $g\ c\ e$ (or $b\ d\ f$) we again have the spectra in the form of equilateral triangles; but as they are now further apart, the sides of the triangles in the two cases being as $\sqrt{3} : 1$, the hexagons will be smaller and three times as numerous. Their sides will also be arranged at a different angle to those of the first set. The hexagons may also be entirely obliterated by admitting only the spectra $g\ c$ or $g\ f$ or $b\ f$, &c., when new lines will appear parallel, at right angles, or obliquely inclined to the median line.

By varying the combinations of the spectra, therefore, different figures of varying size and positions are produced, all of which cannot of course represent the true structure.

Not only, however, may the appearance of particular structure be obliterated or created, but it may even be *predicted* before it has been actually seen under the Microscope. If the position and relative intensity of the spectra in any particular case is given, the character of the resultant image can be worked out by mathematical calculations solely.

A remarkable instance of such a "prediction" (as we may call it), is to be found in the case recorded by Mr. Stephenson,* where a mathematical student, who had never seen a diatom, worked out the purely mathematical result of the interference of the six spectra *b–g* of Fig. 105 (identical with *angulatum*) giving the drawing copied in Fig. 107. The special feature was the *small* markings between the hexagons, which had never been seen on *angulatum*.

Fig. 107.



On Mr. Stephenson, however, re-examining a valve—stopping out the central beam, and allowing the six spectra only to pass—the small markings were found actually to exist, though they were so faint that they had escaped observation until the result of the mathematical deduction had shown that they *ought* to be seen.*

It is therefore shown that dissimilar structures give identical microscopical images when the difference of their diffractive effect is removed, and conversely similar structures may give dissimilar images when their diffractive images are made dissimilar. A purely dioptric image produced by homofocal rays answers point for point to the object on the stage, and therefore would enable a safe inference to be drawn as to the actual nature of that object: the interference images of minute structure, however, stand in no direct relation to the nature of the object, so that the visible indications of structure in a microscopical image are not always or necessarily conformable to the actual nature of the object examined.

Or as Professor Abbe puts it, minute structural details are not as a rule imaged by the Microscope geometrically or dioptrically, in accordance with the real nature of the object, and cannot be interpreted as morphological but only as physical characters, not as *images* of material forms, but as *signs* of material differences of composition of the particles composing the object, so that nothing more can safely be inferred from the image as presented to the eye than the presence in the object of such structural peculiarities as will produce the particular diffraction phenomena on which the images depend.

The larger the number of diffracted rays admitted, the greater the similarity between the image and the object, a true image of the real structure being produced only when all the diffracted rays from

* See this Journal, i. (1878), p. 186.

the object are admitted. The consideration of the diffraction pencils, their admission or non-admission into the field, bears therefore, not merely on the resolving power but on the *delineating power* of the Microscope, i. e. on the fundamental aim of microscopical observation *to see things as they are.*

Those who have recognized these facts of microscopical vision, know how difficult it has been to induce those who have always looked upon the Microscope as essentially belonging to geometrical optics not merely to recognize that it has largely passed into the domain of physical optics, but even to listen to the suggestion. The difficulty is not in their grasping the fact when it is once explained to them, as the experiments which illustrate it are very simple; but is of the same kind as that which prevented our forefathers even investigating the (to them) absurd allegation that the earth revolved on its axis.*

(b) *Coarser Objects.*

It will be useful to note for those who have not had the opportunity of following the continuation of the researches of Professor Abbe, that they have enabled him to complete the diffraction theory.

In his original paper Professor Abbe established, as we have shown above, the application of the theory to the delineation of minute structures which by their diffractive effect produce a perceptible breaking up of the incident (transmitted or reflected) rays, the images of the coarse parts of microscopical objects (measured by considerable multiples of the wave-length) being treated as depicted on the ordinary dioptric method, giving what was called the "dioptric image," the minute structural parts giving the "interference image."

The further researches showed that strict dioptrical delineation, by simple collection of the emitted rays to a conjugate focus, is confined to the delineation of self-luminous objects, those which radiate by transmitted or reflected light being depicted on the interference principle.

The explanation of the mode of delineation of coarse structures would then stand thus:—The image of any given structure becomes, as we have seen, more and more similar to the true composition of the object, when a greater and greater portion of the whole diffraction group is admitted to the objective, or the lost portion is reduced more and more. The dissimilarity of the microscopical image in relation to the object depends only on the *loss of diffracted rays*, and is therefore in general increased when the objective's aperture excludes more and more of the bent-off beams. The image of a structure which is

* A striking instance of this difficulty will be found in the statement which recently appeared in print that "these mysterious spectra are simply visionary" (Eng. Mech., xxxii. 1880, p. 300), a statement which was made with so much genuine conviction that it *must* be true that it was not thought necessary to check the assertion by an experiment which it would not have taken five minutes to make! And this in an age which has seen sound conveyed to a distance by a beam of light (or heat), and in which no one any longer ventures to discredit in advance a reported new discovery merely by the suggestion that it outrages the notions that we were taught in early life, and which we had got to believe were so simple and fundamental that it was impossible they could be either erroneous or capable of qualification.

delineated by means of one or a few diffraction beams, is in general a more imperfect and incomplete image than another which is depicted by means of a greater part of the total diffraction group. The images of coarse objects are perfectly similar to the objects, because even small apertures are capable of admitting the *whole group* up to the limit of vanishing intensity of the deflected rays.

To put it in another way. The interference image of any object must become more and more similar to a simple dioptric image when the elements become coarser and coarser, and the breaking up of the rays by diffraction is confined to smaller and smaller angles. Whenever these angles of the diffraction groups are very small compared to the aperture angle of the objective, the result of the interference effect is the same as if there were *no* diffraction at all, and the object were depicted as if self-luminous.

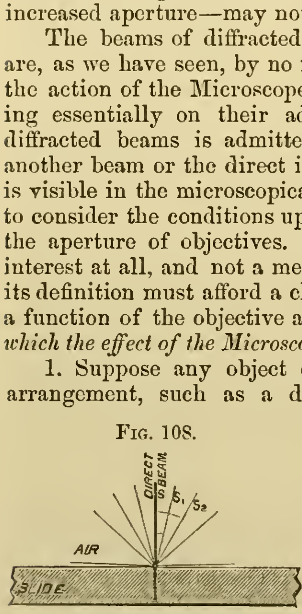
(2) The Delineating Power of Objectives and Aperture.—So far we have not supposed the existence of immersion objectives or of apertures exceeding the equivalent of 180° angular in air, indeed Prof. Abbe's views were developed at a period when opticians had not recognized the possibility of constructing objectives with so large apertures.

The two considerations with which we have however dealt—the existence of apertures in excess of 180° in air, and the function of increased aperture—may now be combined.

The beams of diffracted light which emanate from any structure are, as we have seen, by no means indifferent and accidental things in the action of the Microscope, the efficiency of the instrument depending essentially on their admission. Unless at least one of these diffracted beams is admitted by the objective, together with either another beam or the direct incident pencil, no indication of structure is visible in the microscopical image. It will be important therefore to consider the conditions upon which this admission depends, that is, the aperture of objectives. If aperture is of any general scientific interest at all, and not a mere matter of abstract dioptrical doctrine, its definition must afford a clear and correct indication of so important a function of the objective as *the admission or non-admission of rays on which the effect of the Microscope is based*, that is, of its *delineating power*.

1. Suppose any object composed of minute elements in regular arrangement, such as a diatom valve; and to confine the consideration to the most simple case, suppose it illuminated by a *narrow axial* pencil of incident rays. If this object is observed successively in air and balsam, or any other dense medium of refractive index n, the radiation from every point of the object is, in consequence of the diffraction effect, composed of an axial pencil S, Fig. 108 (the direct continuation of the incident rays), and a number of bent-off pencils S_1, S_2 . . . inclined at the angles w_1, w_2 the first, second . . . deflected beams on all sides. Denoting by λ the wave-

Fig. 108.



length of the light (of any definite colour) in air, and by δ the distance of consecutive elements of the structure, then the wave-length of the same rays within a medium of the refractive index n will always be $\frac{\lambda}{n}$. By the Fraunhofer formula the angles w_1, w_2 . . . of the first, second . . . deflected beam within the medium are defined by the equations

$$\text{Sin } w_1 = \frac{\frac{\lambda}{n}}{\delta}; \ \sin w_2 = 2\,\frac{\frac{\lambda}{n}}{\delta},$$

or

$$\text{Sin } w_1 = \frac{\lambda}{n\,\delta}; \ \sin w_2 = 2\,\frac{\lambda}{n\,\delta}$$

(n is of course $= 1$ for air).

In passing from air to the medium n the *sine* of the deflection angle of the first, second . . . bent-off beam is *reduced*, therefore, in the exact proportion of n, and the angle itself is reduced also—that is, the whole fan of the diffracted rays is *contracted* in comparison with its extension in air.

If now any dry objective (with a given angular semi-aperture u) is capable of gathering-in from air the first, or the first and second diffraction beams on every side of the axial pencil, another objective with a more dense front medium of the refractive index n, will be capable of admitting, from within the dense medium, exactly the *same* beams (no more and no less), if its angular semi-aperture v is *less than* u in the proportion—

$$\sin v : \sin u = 1 : n,$$

or if

$$n \sin v = \sin u,$$

all other circumstances—object and illumination—remaining the same.

For example, a diatom for which the distance of the striæ is $0 \cdot 6\ \mu$, will give the *first* bent-off beam of green light ($\lambda = 0 \cdot 55\ \mu$), in *air* under an angle of $66 \cdot 5°$. This will be just admitted by a dry objective of 133° angular aperture. In *balsam* ($n = 1 \cdot 5$), the same pencil will be deflected by $37 \cdot 5°$ only, and would be admitted therefore by an objective of not more than 75° balsam-angle. Again, if the distance of the lines should be greater, as $1 \cdot 2\ \mu$, the *second* deflected beam would be emitted in *air* under an angle of $66 \cdot 5°$, but in *balsam* the *third* would attain the same obliquity. Whilst now the dry objective of 133° air-angle cannot admit more than the two first diffraction beams on each side of the axis, the immersion of 133° balsam-angle is capable of admitting from balsam three on each side under exactly the same illumination.

It follows, therefore, that a balsam-angle of 75° denotes the same aperture as an air-angle of 133°, and a balsam-angle of 133° a much greater aperture than an air-angle of the same number of degrees, and in general two apertures of different objectives must be equal if the sines of the semi-angles are in the inverse ratio of the refractive index of the medium to which they relate, or, which is the same thing, if the product ref. ind. × sine of the angular semi-aperture ($n \sin u$) yields the same value for both.

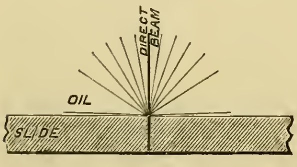
Thus the *unequal equivalent* of equal angles is shown in this way also, as well as by the purely dioptrical method, and numerical aperture ($n \sin u$) is seen to be the true measure of the greater or smaller capacity of an objective for collecting light—i. e. the true image-forming light—from the object.

2. Suppose one and the same (structured) object to be observed by a dry objective of a given air-angle, at first in air uncovered, and then in balsam protected by a cover-glass. According to Fraunhofer's law, the group of diffracted beams emitted from this object *in balsam* is *contracted* in comparison to the group in air in the ratio of the refractive index. But according to the law of refraction, this group, on passing to *air* by the plane surface of the covering-glass, is *spread out*—the sines of the angles being compared—in the ratio of the same refractive index. Consequently the various diffraction pencils, the first, second . . . on every side, after their *transmission into air*, have exactly the same obliquity which they have in the case of direct *emission in air* from an uncovered object.

If, now, any dry objective of, say, 133° air-angle is capable of admitting a certain number of these pencils from the uncovered object, it will admit exactly the *same* pencils from the balsam-mounted object. The contracted cone in balsam of 75° angular aperture embraces all rays which are emitted in air within a cone of 133°.

It is, therefore, shown in this mode also, as it was before dioptrically, that there is no loss of aperture by mounting the objects in balsam or other dense medium; the aperture of an objective, whether great or small, is *never* cut down thereby. No ray which could be taken in from the uncovered object is lost by the balsam mounting. The full and undiminished aperture of a dry objective always bears upon the object with every method of mounting, provided there is a plane surface of emergence.

Fig. 109.



3. A comparison of Figs. 108 and 109 will show that a cone of 82° within the balsam medium embraces *all* the diffracted rays which are emitted from the object in air or transmitted from balsam to air. This, however, is not the totality of rays which are emitted in the balsam. The formula of Fraunhofer accounts for as many (k) diffraction beams on each side of the direct beam as are reconcilable with the condition $k \frac{\lambda}{n \delta} < 1$, because the expression gives the *sine* of the angle of deflection.

The number of the emitted beams is therefore *greater* in balsam than in air in the same ratio as the refractive index.

A structure of δ (distance of the elements) $= 4 \times 0 \cdot 55\,\mu = 2 \cdot 2\,\mu$

emits in balsam *six* distinct beams on each side of the direct beam, but in air only *four* (see Figs. 108 and 109); the fifth and sixth are completely lost in air, as there is no angle of obliquity whose sine is >1. A dry objective of an angular aperture closely approaching 180° will not even take in the fourth deflected beam, as this is deflected at an angle of 90°. But any immersion glass of a balsam-angle slightly exceeding 82° will take in the fourth, and if the balsam-angle should exceed 112° it will take in the fifth beam also, provided the object is in balsam and in optical continuity with the front of the lens.

Thus again it is shown, in agreement with the dioptrical method, that an immersion objective of balsam-angle exceeding 82° has a wider aperture than any dry objective of maximum angle can have, for it is capable of gathering in from objects in a dense medium rays which are not accessible to an air-angle of 180°.

Recalling what was before explained as to the progressive enlargement that takes place in the diameters of the emergent beams of dry, water-immersion, and oil-immersion objectives of maximum aperture (see Fig. 54), it will be readily seen how the enlarged diameters will allow of the admission of additional diffracted beams.

The action of the obliquity of the incident light may also be seen by comparing Fig. 108 with Fig. 57. In the latter case the direct beam is no longer vertical but horizontal, so that new spectra can now enter the field, and particular structure before invisible comes into view.

These conclusions are simply inferences from two well-established optical laws—that of Fraunhofer, and the law of refraction. They are supported to the full extent by observation under the Microscope. Though we cannot see the contraction of the diffraction group in the denser medium, and its subsequent extension by the transmission into air, we can directly observe the various beams at their entrance into the objective by observing the spectra in the clear opening of the system. In this way it is shown—

1. If any structure is observed successively by a dry objective of *large* air-angle, and by an immersion objective of *moderate* balsam-angle (much less than the air-angle of the former), we never lose any spectral beam which is visible with the dry objective.

2. If we examine the same object with the same dry objective at first in air, and afterwards in balsam, we always see the same spectra.

3. Observing a balsam-mounted object with a wide-angled immersion glass (balsam-angle $>$ 82°) we see *new* spectra which, under the same illumination, are never taken up by any dry objective nor by the immersion objective when the object is in air.

V. The Value of Wide-angled Immersion Objectives.

What is the result of the preceding demonstrations?

First. It is shown that, contrary to the "angular" theory, a wide-angled immersion objective *has* an aperture (in the true and legitimate sense of the term as meaning "opening") exceeding that of 180° angular in air, that is in excess of the maximum to which a dry objective can attain, so that the contrary view must now be ranked with the belief in the flatness of the earth which still lingers in places.

Second. Whilst it is conceded by all parties that increase in aperture is accompanied by an increased effect in microscopical vision, the reason cannot be explained on the "angular" view. When it is seen, however, that microscopical vision is not, as erroneously supposed, subject only to the same conditions as ordinary vision, the explanation of its true character is shown to lead to the establishment of the *diffraction*, in lieu of the *dioptrical*, theory.

Thirdly. Dry objectives must be considered to represent an imperfect phase of construction *so far as regards the delineation* (not "resolution" merely) *of very minute objects.* Dry objectives are and will always be of the highest practical value in those lines of research in which low and moderate apertures are sufficient for the perfect delineation of the objects under investigation. As soon, however, as minute objects are observed which require *high amplifications* in order to be *seen*, dry objectives cannot compete with immersion inasmuch *as high apertures are necessary in order to obtain perfect delineation.* No improvements in construction, therefore, can render a dry objective, whose aperture is limited to 1·0, equal for the delineation of minute objects to a wide-angled immersion objective whose aperture is limited only by the higher figure which represents the refractive index of the denser immersion medium.

For any of the purposes, therefore, for which the delineation of very minute objects is required in the Microscope—and it need hardly be said that this is by no means *all* purposes—a perfectly constructed wide-angled homogeneous-immersion objective is necessarily to be preferred to all others, for the simple reason that it enables us to see more, and more perfectly.

It will be recognized that this is not a merely abstract result, of interest to no one but the optical mathematician, but that it is a *practical* result in the fullest sense of that term.

β. Collecting, Mounting, and Examining Objects, &c.

Aeroscopes.—Dr. R. L. Maddox comments upon the remarks of M. Miquel on this subject,* particularly in reference to his statement that his aeroscope à girouette gathers 100 times more germs than the aeroconiscope Dr. Maddox used in 1870.

The aeroconiscope was not exposed, as supposed by M. Miquel, for the entire twenty-four hours, except in one case, but was removed during rain and at night, except on one other occasion when it was left exposed for eighteen hours. Tabulating the total number of hours for the several daily exposures in the different months, the result is as follows:—

April 19—	Exposures	157	hours,	against total time,	456	hours.
May 24	,,	$213\frac{1}{2}$	,,	,, ,,	556	,,
June 23	,,	235	,,	,, ,,	652	,,
July 19	,,	225	,,	,, ,,	456	,,
Aug. 10	,,	116	,,	,, ,,	240	,,
Sept. 22	,,	203	,,	,, ,,	528	,,
Oct. 26	,,	175	,,	,, ,,	624	,,
Nov. 12	,,	90	,,	,, ,,	165	,,

The position of the apparatus was much sheltered, especially by the houses, from the more prevalent winds, S.S.W. and W. The garden was surrounded by a wall and contained many trees. The small village lay chiefly at the back of the house, north and east, a brewery being at a considerable distance away. The house faced a large open field, with the Solent beyond, the town of Southampton being at some distance on the north and north-west. The instrument was also coarsely made, the funnels being of tin, so doubtless many particles were arrested on their path to the thin cover-glass.

The enumeration was ieal, and made immediately upon the thin cover being removed, and not by comparison of the relations between the surface of the exposed gathering-glass and the field of the Microscope. Moreover, neither pollen nor starch grains were counted, which enter into M. Miquel's category, to be allowed for by a percentage which, to be correct, should vary according to the season; for in summer we may expect more pollen, and in the chief brewing months more cells of yeast and starch from the breweries of a large city. May there not also be some doubt, Dr. Maddox asks, of the correctness of M. Miquel's method of calculating the results of the exposures of *forty-eight hours*, for is it not possible that many yeast-cells and small torulæ may within that period, on warm moist days especially, develope, and the attempt to distribute the dust equally throughout the sticky material used, by means of a needle-point, be liable to detach or disjoint the newly formed or secondary cells, and thus add directly to the original number for calculation?

No doubt in strong winds many of the lighter particles are carried much higher than the level of the instrument; nor is there any possibility of obtaining exactness unless by using an aspirator that could draw through the instrument a column of air of a given height, always turned to face the wind; for if the velocity of the latter exceed the

* See this Journal, iii. (1880) p. 1032.

draught of the aspirator, a large number of particles must be carried past without entering the aeroscope; and if the power of the aspirator exceed the force of the wind, it would tend to lift the light but quiescent particles in the immediate proximity.

The object which engaged Dr. Maddox's attention at the time was to ascertain by cultivation whether the collected germs were capable of germinating under the measures used,—in fact, whether they were living or dead; hence glycerine was discarded. It is gratifying to see that M. Miquel intends to continue bringing his great patience and ingenuity to the experimental examination by cultivation, in flasks, of the "Schizophytes de l'atmosphère," the more important part of the inquiry. The advantages he enjoys at the Park of Montsouris have already yielded most interesting results. Although it is not likely that we shall ever be able to exactly imitate the processes at work, as temperature, moisture, pabulum, &c., which lead to rapid development of septic elements within a highly organized living being; yet the recognition of trustworthy cultivations out of the body is amongst the first conditions for understanding the agency, whether hurtful or otherwise, of the minute organisms which so largely surround us, enabling us to test their properties by inoculations on the lower animals at any stage of their cultivation. Still such studies will require to be extended over a large area in different countries before we shall be able to arrive at their real estimate in reference to disease, whether of man or animals.

Slip-cleaning Instrument.*—Mr. Scarle brought this instrument before the members of the Postal Microscopical Society at their last meeting. It consists of a flat piece of wood $15 \times 4 \times \frac{1}{2}$ inch. Along each side of this and close to the edge is fastened a slip of wood $12 \times \frac{1}{2} \times \frac{1}{4}$ inch, thus leaving a clear space of 3 inches between them, and in which the slips are arranged for cleaning. Two other loose strips $14 \times \frac{1}{2} \times \frac{1}{4}$ inch are now placed upon the ends of the glass, and are each secured at one end by being slipped into a staple. That portion of the wood on which the slip rests is padded with cloth. The rubber for polishing the centre of the slips is made by glueing two thicknesses of cloth on the end of a large cotton reel; a piece of washleather is stretched over the cloth and secured by being tied to the middle of the reel. It is desirable to have two of these padded reels, one to use with putty powder, the other to give the final polish.

"Opaque" Illumination by the Vertical Illuminator.—On this subject Professor J. E. Smith remarks † that definition of surface (as distinguished from "penetration") is *par excellence* the legitimate as well as the safest field for microscopical investigations of an advanced nature over objects more or less opaque.

"All attempts to illuminate objects by reflected light under high amplifications had signally failed, until about five years ago, when Mr. Geo. W. Morehouse, of Wayland, N.Y., made the important dis-

* 'Northern Microscopist,' i. (1881) p. 68.
† Amer. Journ. Micr., v. (1880) pp. 204–6.

covery of the conjoint use of the vertical illuminator with American *immersion* objectives of wide balsam apertures.* By way of demonstration, Mr. Morehouse exhibited the *Podura* scale under amplifications of 4000 diameters, as well as other objects.

"Thus it appears that until five years ago there was no known means of working high powers with reflected light, and when we remember that the vertical illuminator proved to be a difficult instrument in the hands of one not expert either in its use or that of the wide-apertured objectives—that probably 50 per cent. of those who have made the attempt have failed to use it successfully—the reasons become apparent *why* so little has been accomplished in this direction.

"This is a *natural* field of Microscope investigation; we thus see things through the Microscope as we see them day after day with the naked eye, namely, by light reflected from the surface. It often thus occurs that such eye examinations of the surface suggest the propriety of dissecting the object into smaller and smaller parts, so that the object may be further inspected in detail. The same holds good when it is under the objective and vertically illuminated.

"The wider the balsam aperture of the immersion objective the better its conjoint work with the vertical illuminator. Here we have additional evidence of the value of wide apertures.

"Under the vertical illuminator the dry valves of *S. gemma* surrender their true structure. It will be seen that these shells are enveloped in an *exceedingly* thin membrane, which, in most cases, is ruptured, or torn from certain portions of the shell, and that it is only through the opening thus formed that the underlying 'markings' are truly seen. If the same valve be viewed by transmitted light the image will be shown falsely owing to the illumination."

[See the next note as to this *not* being "*opaque*" illumination.]

Amphipleura pellucida by Reflected and Transmitted Light.—At the ordinary meeting of the Society on 10th November, 1880, Mr. T. Powell, jun., exhibited *A. pellucida* (dry on cover-glass) in a somewhat novel manner—illuminated from above and below at the same time.

With one lamp placed at the side, the light was reflected by the vertical illuminator upon the posterior surface of the objective, and thence condensed upon the object, the lens acting as the condenser for the illumination and as object-glass at the same time. By the adjustment of a side diaphragm applied to the vertical illuminator, and by rotating the object into the required position, this illumination developed an appearance of "dotted" superficial structure. Another lamp was used to direct a pencil through the ordinary achromatic condenser of Powell and Lealand. By the slot diaphragm transmitting a small pencil refracted very obliquely through the margin of the condenser, this illumination exhibited the usual transverse striæ. A screen was arranged to cut off the illumination from either lamp, so that the object could be seen by either illumination successively.

The object was viewed by the new $\frac{1}{12}$ oil-immersion (with cor-

* See this Journal, ii. (1879) p. 194.

rection-adjustment) of Mr. T. Powell, jun. The illumination by the vertical illuminator is well known to be one of the severest tests for the corrections of an objective; and the lens, it may be said, bore the test excellently. Its large aperture provided abundance of light, so that the fourth or fifth eye-piece could be used with either kind of illumination.

It was pointed out by Mr. Stephenson at the meeting in March that the illumination by the Vertical Illuminator had been erroneously supposed to be in this case "opaque"; whereas, in fact, the light is *totally reflected* from the internal surface of the base of the object. The proof of this is that no objective whose limit of aperture does not (approximately) exceed twice the critical angle from glass to air (82°) will illuminate the object; the whole (or very nearly so) of the light is transmitted through the object as it is not *opaque* enough to reflect back by ordinary reflection sufficient light to produce an image of its surface. But objectives of greater aperture provide an outer zone of rays beyond the critical angle; these rays cannot emerge at the base of the cover-glass of a dry mount adherent thereto *except* where the object adheres; the rays then pass into the object and suffer total reflection (to a great extent) at *its* base, and thus provide extremely oblique reflected light, which is transmitted upwards through the body of the object, and renders the surface structure visible.*

The late F. A. Nobert.—At the March meeting of the Society the announcement was made of the death of Mr. F. A. Nobert, of Barth, Pomerania, whose rulings of fine lines on glass have for many years past been regarded as marvels of dexterity by the scientific world. Mr. Nobert's fame is especially connected with the production of test-plates for the Microscope, particularly the plate known as the 19-band plate, on which successive bands of lines are ruled of increasing fineness of division, from the rate of 1000 to the Paris line to 10,000 (equal approximately to 112,000 to the English inch). It was formerly Mr. Nobert's opinion that the last four bands of his 19-band plate would never be seen resolved in the Microscope. This opinion he was constrained to withdraw after careful inspection of photographs of the whole series of bands by Dr. J. J. Woodward, of the Army Medical Museum, Washington, U.S.A., from which an accurate count of the lines actually ruled was made by Dr. Woodward, and admitted by Mr. Nobert. Mr. Nobert then proceeded to make a new plate of 20 bands of lines varying from 1000 to 20,000 to the Paris line. The lines on the tenth band in this latter plate corresponded in fineness of division to the 19th band of the former plate. The microscopists of the future have therefore Nobert's legacy before them to resolve the lines on the later test-plate. Mr. Nobert was extremely reticent as to the method of producing his fine rulings, and it is doubtful if he has communicated to any one the secret of his process of making and adjusting the ruling points.

* See the discussion at the March meeting, *infra*, p. 373.

diatoms containing a small amount of organic matter; such are the earths of Java (consisting mainly of *Melosira orichalcea*), Lapland, the mountain-meal of Switzerland and Finland, and the fossil-meal of Mount Amiata, in Italy, which contains about 80 species. A mixture of marine algæ (*Fucus*, various species, *Rhytiphlœa*, *Cladophora*, *Ceramium*), of Corallines and Sertularians, is known to druggists under the name of Corsican moss, in which as many as 120 species of diatoms have been found. They also occur as the Carrigeen moss (*Chondrus crispus*) used in pharmacy, and on other marine plants, whose ashes have been from time to time used as medicine (e. g. *Ulva lactuca*, *Fucus vesiculosus*). In this connection, however, they must be regarded as indifferent substances, producing no appreciable effect when thus taken, as 84 per cent. of them is composed of silica, and only 12 per cent. of water and organic matters; the latter constituents being the protoplasm and the accompanying sap and the endochrome, which are all, with the exception of the phycoxanthin of the latter body, already found in the accompanying Algæ. They have a further interest, in the part which they play when living in fresh waters, in purifying them from the excess of carbonic acid and waste azotized matters, and in giving out at the same time more oxygen than any other aquatic plants.

In their relation to *geology*, diatoms furnish proofs of the aquatic origin of the strata in which they occur, of their age, and of the saltness or freshness of the water in which they were deposited, and of whether near the coast or in deep water, by the difference between the species which are associated with each of these conditions.

Diatoms are connected with the useful arts through *agriculture*, to which they are of assistance under the form of guano. Water rich in diatoms is more fertilizing than that which is not so, as the latter generally contains an undue amount of mineral salts.

Diatoms are used—as tripoli—to polish metals, stones, and jewels, and form a constituent of dynamite. Their most important application to the arts here mentioned, is that of serving as tests for the Microscope.

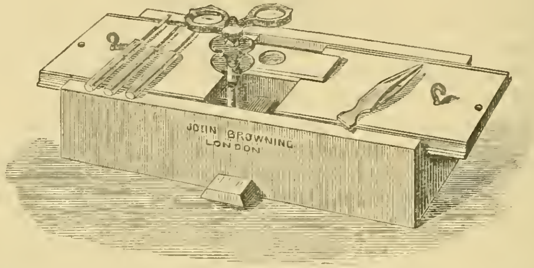
MICROSCOPY.

a. Instruments, Accessories, &c.

Houston's Botanical Dissecting Microscope.—This instrument (Fig. 116), designed by Mr. D. Houston, author of 'Practical Botany,' is intended to provide working botanical students with a dissecting Microscope at a very low cost.

The box measures, when closed, 9 inches long, 4 inches wide, and 2 inches deep, and is so constructed that, by using a divided sliding lid (which acts as a support for the dissecting stage), a rest for the wrists is secured while the hands are employed in dissecting. The duplex lens, which gives three powers, magnifying 4, 6, and 10 diameters, is screwed to the end of a brass focussing tube, which moves upon a brass pillar attached to a sliding bar at the bottom of the box. The lens may at any time be unscrewed and carried in the pocket. The dissecting stage is a cork slide, plain on one side for general work, but provided with a shallow cell on the other, for

Fig. 116.



the dissection of such objects as small glossy seeds which "fly" under the needles. A pitted glass slide, to be used when the object is best dissected under water, is also provided.

Jaubert's Microscope.—Fig. 117 shows a Microscope of somewhat unusual form, made by M. Jaubert of Paris as long ago as 1866.

Besides the ordinary movement of inclination from the vertical to the horizontal position, the stand is provided with a *lateral inclining movement* at right angles to the former, by which the optical body and stage can be completely inverted on an axis running through the trunnion bar. M. Jaubert claims that this facility for inverting the Microscope may be of use in chemical experiments.

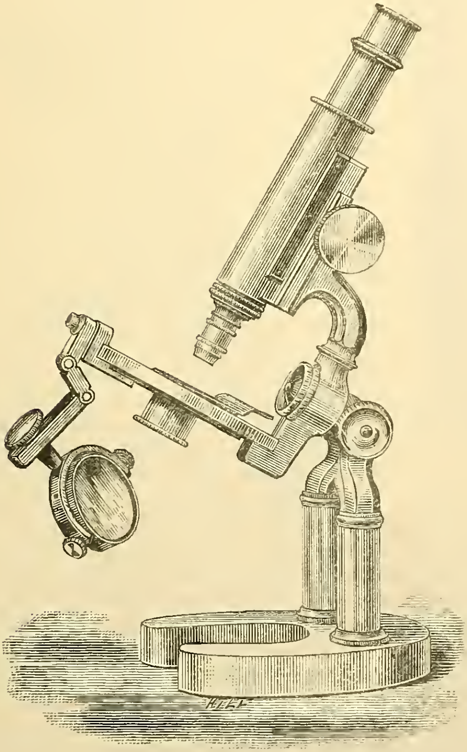
The attachment of the *mirror* can also be slid round the edge of the stage from side to side, and sundry articulations give a great range of motion to the mirror either above or below the stage.

The *fine adjustment* is by means of a differential screw attached to the nose-piece of the optical body. This system appears to have been experimented with at various intervals since the days of Pritchard, but has not met with permanent favour. In the 'Quarterly Journal of Microscopical Science,' iv. (1856) p. 92, is a paper "On a New Form of Microscope," by Mr. R. Warington, with a figure of the fine adjustment, which was stated to be "constructed on the principle of a common union-joint, the outer half of which works in a male screw at the extremity of the body-tube, and acts against a spring in order to maintain a constant bearing. . . . ." Mr. James Swift also some years ago devoted attention to working out a somewhat similar plan, and in fact exhibited a Microscope embodying the fine adjustment at the International Exhibition of 1862. It may also be noted that a Microscope of amateur construction (by Mr. W. A. Bevington) having a fine adjustment of this kind at the nose-piece of the body-tube, has been exhibited several times at the Society since 1875 when it was made.

The fine focussing by means of a differential screw, together with an analogous system for the coarse adjustment, and several other curious mechanical movements as applied to Microscopes, &c., formed the subject of an elaborate series of patents registered in England by M. Jaubert in 1866, to which we propose to refer hereafter.

Mr. J. Mackenzie also describes and figures * a swinging sub-stage made upon the same principle as the preceding. To the under part of the fixed stage-plate an angular plate is attached, having a

Fig. 117.

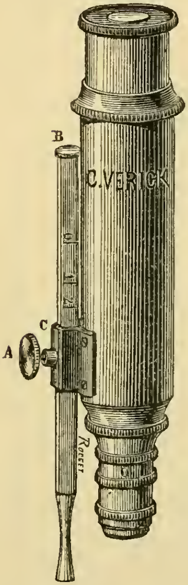


swivel joint on which a stem with rack swings. A pinion works on the rack and carries an arm with either a single or compound lens which should be so adjusted as to be central with the optical axis of the Microscope. At the end of the stem is a small concave mirror. The lens can be raised or lowered by the pinion or swung to any angle below or above the stage. The angle-plate should be made and fixed so that the centre of the movable joint or swivel coincides with the top of an ordinary object-slide when it lies on the stage.

* Journ. Quek. Micr. Club, vi. (1880) p. 170, pl. xii.

Vérick's Skin Microscope.—This (Fig. 118) is intended for the examination of the skin. The tube, with eye-piece and objective, is of the usual form, but is attached to a lateral bar B, which is of brass, with a piece of ivory at the lower end. This bar serves for the adjustment of the Microscope to the proper focus. It is graduated in accordance with the objectives used, and when the number corresponding to the particular objective is brought to the point C, and the end of the bar rested upon the object under observation, the surface can be examined with facility. The screw A serves to clamp the bar and tube together.

Fig. 118.



Watson's Microscope-Stand. — This new stand (Fig. 119) presents several points of novelty, the most notable of which is the inclining motion of the limb carrying the optical body and stage on an axis in a line with the object on the stage. By the simple inclination of the limb, varying effects of oblique illumination can be obtained direct from the mirror, which can be attached for this purpose to the centre of the base, and is then independent of the inclination of the limb.

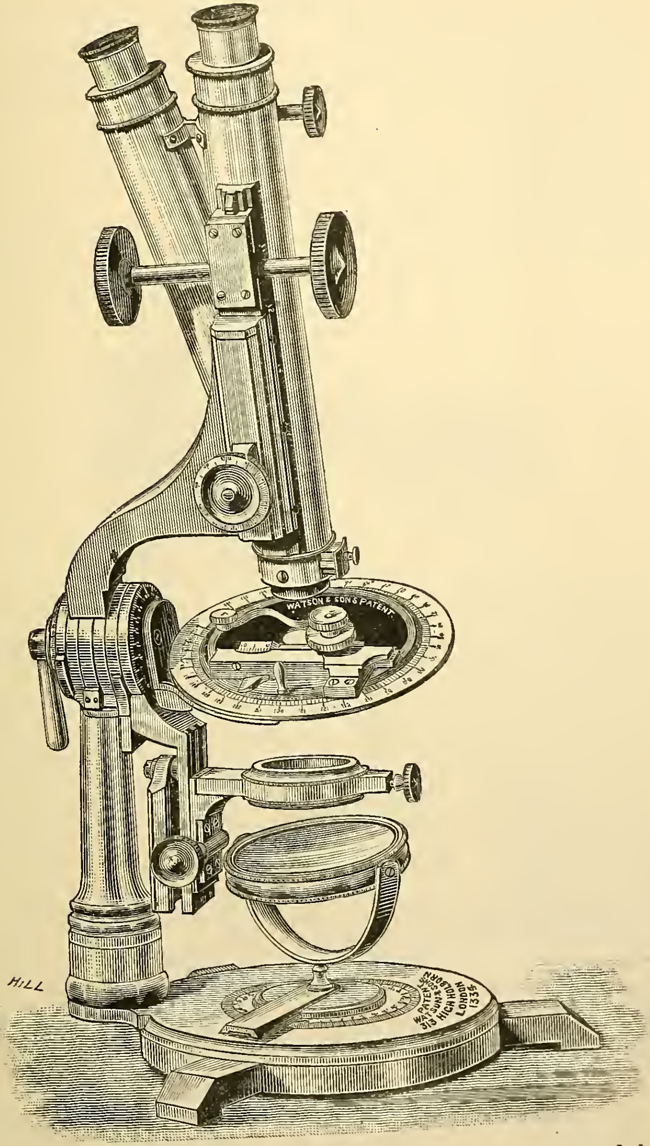
The base of the stand is circular, with three projecting claws; on this base a disk of metal carrying the pillar-support (of the limb, stage, &c.), is made to rotate on the perpendicular optic axis (as in Nachet's Microscope, described in vol. iii. p. 873), and a graduated zone shows the angle of rotation. In the centre of the base a smaller disk (projecting slightly above the general plane) is made to rotate; this disk has a groove into which the mirror-fitting slides, and a spring-notch shows the axial position. The sliding fitting allows the mirror to be placed considerably out of the axis radially, and then the rotation of the circular moving base-plate gives a considerable range of obliquity of light in azimuth—the light from the mirror remaining constantly directed upon the object; this facility obtains with all inclinations of the limb and stage because the object itself forms the centre both of the azimuthal rotation and of the inclination in altitude.

The limb is mounted in a "cradle" joint, at the top of the pillar, permitting inclination from the perpendicular. The angle of inclination is registered upon a graduated ring against the clamping screw.

The optical body is mounted not as usual on the front of the "Jackson" limb, but on the side of it (the *side* of the limb is thus converted into the front).

The coarse adjustment is by the ordinary rack and pinion; the fine adjustment lifts the optical body in a separate slide-fitting by means of a wedge-shaped block acted upon by the conical end of a

Fig. 119.



fine micrometer-screw. The focal distance can be measured by a scale engraved on the slide-fitting.

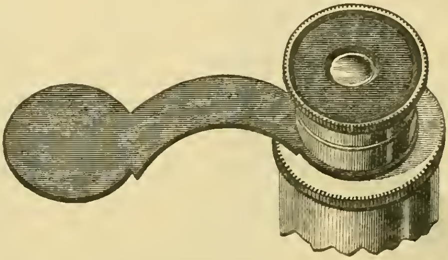
We figured and described the mechanical stage on pp. 300–1.

The substage-bar carries the usual centering fitting for condenser, &c., and swings forwards or backwards concentric with the object on the main stage, and the obliquity of the swing can be registered on a graduated ring immediately behind the stage. The construction is similar to that known as the Ross-Zentmayer. An extra swinging bar is attached behind, into which the mirror can be slid for use in combination with the condenser, &c.

We understand the swinging substage will be somewhat modified by Messrs. Watson in future constructions.

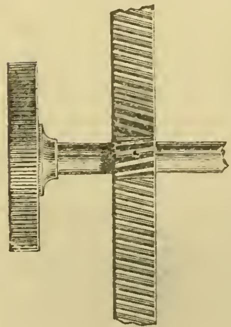
Eye Shade for Monoculars.—Mr. E. Pennock, of Philadelphia, has devised for use with monocular Microscopes the eye shade shown in Fig. 120. The microscopist is always supposed to keep the eye

Fig. 120.



not in use open, but it is well known that there are many who are unable to do so except at the sacrifice of the visibility of the details of the object, especially when, as at soirées and public exhibitions, there is a considerable glare of light upon the table on which the Microscope stands. Some of the devices hitherto in use have been more elaborate than that now proposed, which has the merit of the utmost simplicity and prevents the possibility of other objects being confused with the microscopical image. It slips over the cap of the eye-piece.

Fig. 121.



Diagonal Rack-work and Spiral Pinion.—The occasional application of diagonal rack-work and spiral pinion to the mechanism of the Microscope, dates back from at least the days of Andrew Pritchard. In recent years it has also been adopted, particularly by Ross and by Swift, the latter using it throughout his construction of instruments. From the experience that we have had of this arrangement, we find that it produces a smoother motion than the usual straight rack and pinion; the spiral pinion gripping the rack over a broader surface and holding it for a longer space during the motion.

Fig. 121 (from a drawing communicated by Mr. Swift) shows the construction of average size.

New Fine Adjustment.*—Mr. E. Gundlach, of Rochester, U.S.A., has introduced a device by means of which an extremely slow, fine adjustment can be obtained in addition to the ordinary coarse screw movement. It is described as follows:—

"In working high powers, microscopists have felt the need of a finer adjustment than the ordinary micrometer-screw, which cannot be made much finer and still be durable enough. This need is now supplied by the combination of two screws which give a resultant motion equal to the difference in the threads employed. One of these screws is a little coarser than the ordinary micrometer-screw, and may be used alone as a fine adjustment, and a change can be made instantly from this to the finer motion. Either is given by one milled head located in the usual position of the fine adjustment screw-head on Gundlach's Microscopes, and the change is made by turning a smaller clamping screw having its head over the former. By tightening the clamping screw, the adjustment is in order for the work of the combination; by loosening, for that of the coarser screw only. As the thread of this is a little coarser than the ordinary micrometer-screw, it alone gives a better motion for medium powers than the fine adjustment in common use, a second advantage of the invention."

Oil-immersion Objectives with Correction Adjustment. — With regard to the advantage or otherwise of adopting the correction-adjustment to oil-immersion objectives, Professor Abbe appears to have thought † the errors of centering, likely to be introduced by the movable mounting required for the adjustment, would be so sensibly felt with the high apertures for which the formula was designed, that it would probably be advantageous not to provide the adjustment, but to mount the lenses in fixed settings. Dr. Woodward, of Washington, has also expressed his approval of the fixed settings on the ground that the formula does not practically need a correction-adjustment. The photographs of difficult test-objects produced by him with the Abbe-Zeiss oil-immersions prove, at any rate, that the particular objectives referred to certainly yielded excellent definition with fixed settings.

The objectives recently made on this formula by Seibert and Krafft, of Wetzlar, are also similarly mounted, as are the most recent ones of Gundlach, of Rochester, N.Y.

In England Mr. Stephenson ‡ has acquiesced in the *non-adoption* of the correction-adjustment for these lenses.

On the other hand, Mr. Tolles, of Boston, Mass., and Mr. Spencer, of Geneva, N.Y., have mounted their best objectives on this formula with adjustment. It is also known that Messrs. Powell and Lealand prefer the mounting with correction-adjustment,§ which they have

* Amer. Natural., xiv. (181) p. 346.
† See this Journal, ii. (1879) p. 261 *note*. ‡ Ibid., i. (1878) p. 51.
§ Ibid., iii. (1880) p. 1084.

applied to their most recent $\frac{1}{12}$ (exhibited at the Society on November 10th last).

The convenience of the adjustment has been lately brought out remarkably in testing with the $\frac{1}{12}$ various media for immersion. For instance, with the solution of sulpho-carbolate of zinc in glycerine, having refractive index 1·525 (nearly), the adjustment permitted the lenses to be slightly approximated, and the result was a more perfect correction than by using oil of cedar-wood. The correction-collar was also employed advantageously (with the same lens) on various specimens of *Podura*, some of which, not being in close proximity to the cover-glass, could not have been viewed so well had the lenses been mounted in a fixed setting. These facts were plainly developed by immediate comparisons with several oil-immersions in fixed mounts—by Zeiss, Seibert and Krafft, Gundlach, and Powell and Lealand, which failed to give correct images on all the scales that were not in very close adherence to the cover-glass.

Mr. A. H. Bragdon, of Bangor, Maine, U.S.A., also writes to us on this subject, recommending Mr. Tolles's application of the correction-adjustment on the ground that the *same* objective that is corrected at "closed" point for homogeneous immersion may be used for preliminary observations with water-immersion, the screw-collar enabling the observer to adjust the lens for that medium. He states that, "to the worker this is a great desideratum, and saves a multiplicity of objectives. No one can appreciate this more than a physician who constantly desires to examine with a high power many temporarily mounted objects."

Mr. Bragdon also mentions that he has received from Mr. Tolles a solution of chloride of cadmium in glycerine of exactly 1·525 index. Since the receipt of his letter we have examined a specimen of the fluid (sent by Mr. Tolles), and have found it work well with homogeneous-immersions provided with correction-adjustment, notably a $\frac{1}{10}$ made by him, and Powell and Lealand's $\frac{1}{12}$ above mentioned.

Seiler's Large Stage.—Dr. Seiler, of Philadelphia, has devised a large stage, arranged with mechanical movements, so that it can be made to traverse a distance of about four inches each way. It is claimed to be particularly valuable for examining large specimens, such as sections of tumours, the vocal organs, or anything requiring a large stage movement to bring the whole of the structure successively into view.

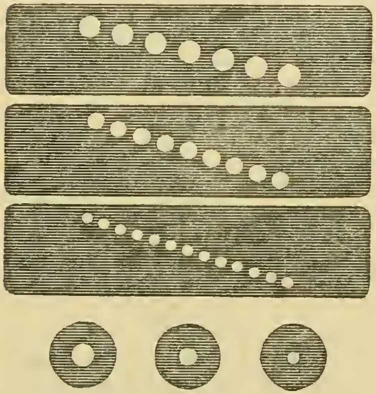
Sliding Stage Diaphragms.—Dr. J. Anthony writes as follows:—

"In going through a series of experiments during the last few months, on the comparative advantages of diaphragms above and below the condenser of the Microscope, I arrived at such satisfactory results that it may be worth while to place them on record; not as a finality, for nothing is likely to be final with the Microscope for many a long day, but that others may take up the matter where I leave it, and that I may have the satisfaction of feeling that I have thought out a most efficient and economic appliance so far as it goes.

Careful manipulators of the Microscope have long felt the damage to the sight which was involved in the attempt to gaze at objects in a full glare of light, and so it came to pass that 'Iris' and other diaphragms were introduced below the condenser to allow only a very small pencil of light to be transmitted; but there was a consciousness that the device was, in degree, tantamount to weakening the light, and it has always been an axiom in microscopy that 'a weak light will never give a brilliant image'; and then came an attempt at additional intensity through a lamp with a flat flame. For resolution this answered admirably, and necessary obliquity obviated glare, but with axial illumination this intensity was not easy to deal with. If the 'Iris' was used to moderate light to a small aperture, lines were thickened, and images of objects looked coarse; if the diaphragm was not freely used the image was poor, flat, and milky, and drowned in a flood of radiance. So diaphragms were constructed, as 'Calotte,' &c., which would act above the condenser, and so, when the full body of light was focussed on the object, the aperture in the condenser would suppress such a number of rays as went rather to injure the image.

There is a positive value in such appliances, and provided they are made sufficiently thin, so as to be easily revolved and easily got at for manipulation, they will do all, or very nearly all, I claim to get from the small and simple contrivance I am about to describe. But it is not to be lost sight of, that these special forms of revolving diaphragms applied above the condenser must of necessity be costly, and confined almost exclusively to what are classed as 'expensive Microscopes,' and it is no small satisfaction to be able to say that experiments have shown me that equal or even superior effects can be got with appliances costing but a few pence, and requiring little more skill in manipulation than a fair amount of delicacy of touch. We recognize that the conditions to be fulfilled are to interpose some screen between condenser and glass slip carrying the object, which shall work easily in the very small space between the usual so-called $\frac{4}{10}$ condenser and the said slip, and which can be made to cut off gradually from the blaze of light all the rays not actually wanted for the perfect illumination of the object under inspection, and at the same time, that such a screen shall be as simple and as little costly as may be compatible with thorough efficiency. It will be seen how far these conditions are met. It would be useless to detail the hundreds of forms of screens or diaphragms experimented on, —all imaginable shapes of aperture and of all sizes, squares, triangles, slits, slots, 'cat's-eyes,' bars, and central stops to apertures, and all more or less unsatisfactory in some way; better to narrate the settling down into the conviction that there really was great advantage in the employment of the simple means shown in the accompanying diagram, where all is given in actual sizes used. It will be seen that there are three slips, of either thin smooth card or vellum, each 4 inches by a full $\frac{7}{8}$ inch, and in each card are punched a row of apertures *oblique to the long axis of the card*, and consequently to the slip of glass when the card as intended is placed beneath the slip upon the stage of the Microscope. It will be seen from construction that on any stage, and with the object to be looked at mounted even excentrically, there would be no sort of difficulty, when the slip is duly clamped and the object brought to centre with a low-power objective, in moving the perforated 'stage diaphragm' right or left so as to let the object be *in the centre of a circle of light.* With any power used, it is easy to understand that a slight push or pull at one of the free ends of the card will, without disturbing the object in the slightest degree, cut off more and more of the unnecessary rays, and as these are gradually eliminated, it will be found that the image changes from a poor, flat, drowned effect to one of great boldness and brilliancy. It is here that the delicacy of touch comes in, for the finest effects of detail are often got with an all but imperceptible movement of the card. One may say that the card material lends itself better to this delicacy than perhaps metal would do, inasmuch as the small amount of friction between slip and card and card and stage respectively, keeps this simple and efficient diaphragm in its place, and it is evident that if card or vellum be the material employed it will have the additional advantage of not scratching the condensing lens. Three apertures of diaphragm were found available, $\frac{1}{4}$, $\frac{3}{16}$, and $\frac{1}{8}$, all with certain advantages with different powers and different classes of objects.

Fig. 122.



It was both interesting and useful to try against this stage diaphragm the effect of corresponding apertures in so many "caps" to the condenser. The circumstances would of course be a little different, inasmuch as with cap to condenser in order to modify the light the said condenser would have to be moved bodily, and the effects would be got by a quasi marginal instead of a central pencil, and so be analogous to some of the effects of oblique light—a condition not at all desirable except for 'resolution' of very diaphanous objects. Anyhow, aperture for aperture, experiment demonstrated that with delicate touches far finer effects could be got from the stage diaphragm than from any sized cap on the condenser, perchance from the light being absolutely central to begin with. One can understand that many conditions would have to be considered in order to determine the point, but I have thought it best to confine myself to practical points. One practical point soon made itself evident, and that was, that the aperture either in card or cap could not be reduced beyond a certain size with advantage. This limit was reached long before one got to the pinhole cap, which opticians supply to condensers for centering purposes.

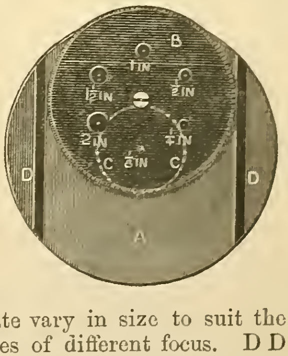
This, then, is the 'sliding stage diaphragm' I have devised, and which I think I may claim as original as it is economic and simple. In my hands it has assuredly improved even the images of objects seen with the fine $\frac{1}{25}$ of Tolles and Zeiss, while with a fine $\frac{1}{2}$ and deep single ocular it has produced such vivid images and shown such detail as almost to suggest the self inquiry of 'What more one wants?' May one trust, then, that this simple bit of apparatus will be a boon to all students of nature through the Microscope? Of course it could be made of various substances. Ebonite suggests itself as appropriate and sightly, while to metal there would be several objections.

In looking to the classes of objects to which this diaphragm would be suitable, those requiring 'resolution' must be at once put on one side, and the advantages looked for in improving the defining power of objectives on the thousand and one objects which interest the microscopist, and these advantages can easily be verified on reticulated structure, and indeed on any delicate tissue apt to be half lost in a flood of light.

Fine as is the image shown by the stage diaphragm in an appropriate object, a *finishing* touch, very slight, to the Iris diaphragm will often bring about a still further perfection of image, which the practical microscopist will not be slow to appreciate."

Bousfield's Rotating Diaphragm-plate.*—Mr. E. C. Bousfield describes a rotating diaphragm-plate, shown in Fig. 123 (reduced size), which he has devised for use close beneath the object on the stage. It consists of a brass plate A, about $\frac{3}{16}$ inch thick, fitting on the stage in the manner of a super-stage by means of two pegs let into holes in the stage itself. A hole C C, about $\frac{3}{4}$ inch in diameter, is bored through the plate, and over this revolves a plate B about 2 inches in diameter, or of such a size as to project beyond the outside of the plate A, and of the central hole. The edge of this plate is milled, and it is about $\frac{1}{16}$ inch thick; it is sunk into the face of plate A just sufficiently to allow of its being turned when the slide is in place. The apertures in this smaller plate vary in size to suit the different sizes of field seen with objectives of different focus. D D are grooves for the usual sliding object-holders.

FIG. 123.



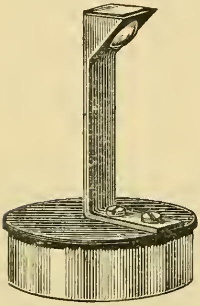
Mr. Bousfield, in view of the fact that diaphragms should always be placed *close under* the object, notes that "Iris" diaphragms (as usually made) fail in this respect, as by the system of construction

* Engl. Mech., xxxii. (1881) p. 495.

some lateral light is always allowed to pass up beyond the field and thus produce fog.

Hyde's Illuminator or Oblique Immersion Condenser.*—The apparatus here shown (Fig. 124) is one of the numerous devices that have been constructed specially for use with immersion objectives having apertures greater than correspond to 180° in air, i. e. greater than the "numerical aperture" 1 (= double the *critical* angle between glass of mean index 1·52 and air, or 82° nearly).

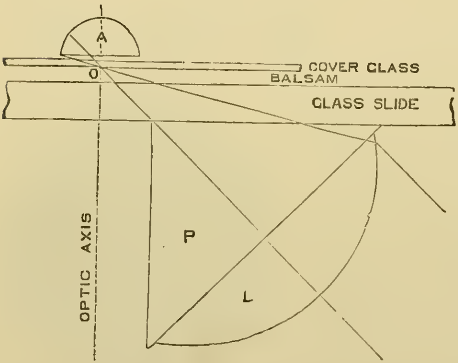
Fig. 124.



It consists of a right-angled prism having a plano-convex lens cemented on the long face, the whole mounted on a metal upright attached to an ordinary substage fitting. The lens is calculated to condense parallel rays to a focus on a balsam-mounted object through a slide of average thickness, with which the illuminator is suitably placed in immersion contact. In this case the ray passing through the axis of the lens without refraction will be incident upon the object at an obliquity of 45° to the optic axis of the Microscope, as shown for the central ray in the diagram of the action (Fig. 125).

A is the front lens of an immersion objective in fluid contact with the cover-glass; O the object in balsam; P a right-angled prism in immersion contact with the base of the slide; L a lens designed to focus the illuminating rays on the object O.

Fig. 125.



For the oblique illumination, as figured, the apparatus must be placed out of the axis of the Microscope. With this obliquity any objective of less aperture than 90° in glass would give a dark field. If placed nearer the axis it is evident that less oblique rays could be used, as the lower half of the lens and prism would then come into action.

As originally made, the device was mounted in a brass plate fitting into the stage opening, but it was found more convenient when placed in the substage with means of varying the degree of eccentricity, upon which depends much of its power as an oblique illuminator.

* See this Journal, ii. (1879) p. 31.

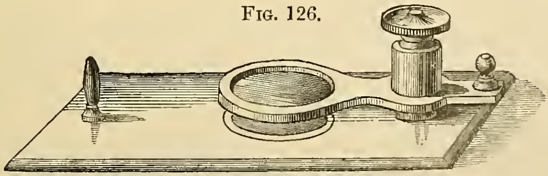
The apparatus was brought from Philadelphia by Colonel G. L. Tupman, R.M.A., to whom we are indebted for the diagram.

High Magnifying Power.—The following will serve to start a column of "Curiosities of Microscopical Optics!" It is not necessary to suppose it to be a hoax, as claims to magnifications not far short of some of those described have previously been made with undoubted seriousness.

"Professor F. G. Fairfield, of New York, has, according to Gaillard's 'Medical Journal,' invented a new objective, giving an increased magnifying power of 49 per cent. It multiplies the power of the Microscope by 7 in diameter and by 49 in area. The visualizing power of the Microscope had heretofore been reckoned to be equal to the showing of an object $\frac{1}{180000}$ of an inch in diameter. That was the limit to which Helmholtz attained. With Tolles' $\frac{1}{75}$-inch, exhibited in the New York Academy of Science two years ago, it was shown that there could be discerned an object $\frac{1}{2500000}$ of an inch in diameter. 'With the $\frac{1}{8}$-inch objective or lens,' said the lecturer, I am able to discern an object $\frac{1}{3000000}$ of an inch in diameter; and if I were to apply the same principle to a $\frac{1}{75}$-inch lens, I should be able to discern an object, making allowance for proper diffusion of light, as minute as $\frac{1}{15000000}$ of an inch in diameter. At that power it would be possible, unless the molecule of albumen be much smaller than it is supposed to be, to discover and demonstrate the molecular constitution of living matter.' The objective invented by Professor Fairfield is composed of three minute lenses in succession. After the rays have passed through the three lenses, formed their image, and crossed, they are then taken up in a field-glass, through a second powerful lens, cross a second time, and a second image is formed from the first. The alleged result is that the penetrating power is very much improved as compared with the ordinary lens, whose power is actually multiplied by more than 49 per cent. The lens is so minute as to be capable of being used only by the aid of the electric light." *

We may again point out that Professor Helmholtz has never asserted that the $\frac{1}{180000}$ inch is the limit of visibility in the Microscope. His researches on this subject referred to the limit to the *power of separating* two portions of an object which are close together.

Fig. 126.

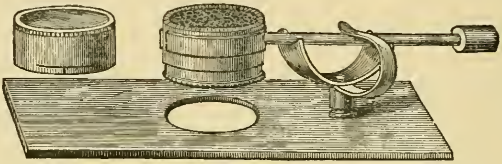


Graham's Compressorium.—Fig. 126 shows this apparatus, which was described, but not figured, at p. 148 of vol. iii. (1880).

* 'British Medical Journal,' 1881, March 5th, p. 353.

Insect Cage.—This (shown in Fig. 127) is intended for the study of live insects. To one end of a 3 by 1 brass plate is attached an upright, supporting a cross-piece at the top on which rests the stem carrying the cage. This is held in place by a spring, and may be rotated or moved longitudinally by a milled head. The cage is constructed on the same principle as the ordinary live-box, but instead of

Fig. 127.



glass, bobbinet is used in order to confine the insect better and without injury. A cover of glass can be used if preferred. The cage may be rotated in the optic axis of the Microscope in order that the object may be illuminated to the best advantage.

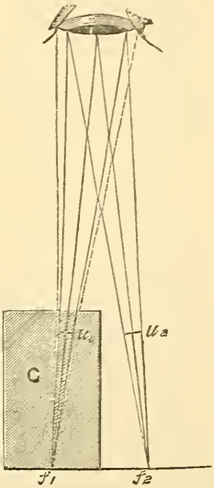
The Essence of Homogeneous Immersion.—With reference to the note at p. 131 it seems to have been supposed that the essence of this kind of immersion objective would have been rested entirely upon the increase of aperture which the immersion fluid renders practicable.

A homogeneous-immersion objective does of course allow of an increase in aperture as compared with a dry objective or a water-immersion objective in the proportion of 1·0 to 1·33 and 1·52—those figures being the refractive indices of the three kinds of objectives,—and the larger apertures so obtained constitute the *practical benefit* to be derived by the investigator from the use of homogeneous-immersion objectives. When, however, we speak of the "essence of homogeneous immersion" it is obvious that the *essence*, in the strict sense of the term, must relate to something which is common to *all* kinds of homogeneous-immersion objectives—not simply to those of high angles only but to low ones also, and the correct use of that term is not affected by the fact that low-angled homogeneous-immersion objectives are not found in practice.

The *essence* of homogeneous-immersion depends therefore on the greater facility which is afforded for correcting objectives of very wide angles; the *practical advantage* is the increase of aperture which can be obtained by the use of a fluid of higher refractive index than water.

Abbe's Apparatus for demonstrating the Increase of Radiation in Media of higher Refractive Index than Air.—We should have added to the description of this apparatus given at p. 343 a note as to the effect of removing the plate B and observing the two fields f_1 and f_2 direct. In this case, of course, the greater brightness is not seen at f_1, but, on the contrary, it looks slightly *less* bright, owing to the greater loss from absorption and reflection in the glass block. Owing to the increase of divergence of the pencil u_1 on its exit from G, the pencil which just fills the pupil of the eye is, *within the glass*, of a *smaller* angle (u_1) than that pencil (u_2) which reaches the eye *direct* from air. Thus the greater intensity of radiation within G is just compensated for by the diminished angles of the pencils which are admitted to the eye ($u_1 : u_2 :: 1 : n$ for narrow-angled pencils).

FIG. 128.



β. Collecting, Mounting and Examining Objects, &c.

Deby's Improved Growing-slide.*—Referring to the growing-slide described at p. 333 of vol. iii., Mr. Deby says that some difficulty seems to have been found in the making of these slides, so that he has devised a still more simple contrivance for obtaining the same results. Take an ordinary glass slip, with a circular hole, say half an inch or more in diameter, in the middle; lay this slip on an ordinary glass slide, not perforated. Then grease the top of the upper or perforated slide just a little way around the circular hole, and join the two slips of glass by means of two rubber rings. The object is then placed on a thin cover-glass, somewhat larger than the hole in the slide; it is then covered by a thin glass cover, $\frac{1}{4}$ inch in diameter; the whole is then turned down and fastened to the slide by the adherence of the grease while the small cover prevents the running of the liquid. The plant or animal under examination finds itself confined in a sort of miniature Ward's case. When not under observation, the growing slide is laid flat in a shallow plate with water just above the line of junction of the two slips of glass, where, by capillarity, it creeps up to the central cell, where evaporation keeps the contained atmosphere in a state of constant and healthy saturation (see Fig. 129).

FIG. 129.

Method for Colouring Infusoria and Anatomical Elements during Life.†—M. A. Certes has endeavoured to find some drug which would stain bodies during life; and he finds that Infusoria placed in a weak solution of chinolin or cyanin are coloured a pale blue, and may continue to live for as many as thirty-six hours; strong solutions are immediately fatal. After being for twenty-four hours in a damp

* Journ. Quek. Micr. Club, vi. (1880) pp. 166–7.
† Comptes Rendus, xcii. (1881) pp. 424–6.

chamber the white blood-corpuscles of the frog, tinged with cyanin, presented amœboid movements; serum was found to dissolve the cyanin better than water.

The coloration appears to be concentrated around the fat-granules of the protoplasm; it is feeble, not to say nil, in the cilia, the cuticle, and the vacuoles; the nucleus and nucleolus escape completely; this is so far an advantage that it makes the observation of the division of these bodies more easy, and affords a demonstration of the difference in chemical composition between them and the surrounding protoplasm. The whole series of observations are interesting as demonstrating that it is not impossible to colour a living cell.

Double and Treble Staining.*—The process of using dyes of two different colours, so as to differentiate more clearly certain parts of a microscopic section of an organ, is, Dr. W. Stirling considers, of the greatest value, and can be employed with excellent results even by students. Having used various methods for the last three years, he now gives a brief account of those combinations of colours which he has found to be most useful for class purposes, and the organs for which each combination is best suited.

(1) *Osmic Acid and Picrocarmine—Blood of a Newt or Frog.*—Mix a drop of blood with a drop of a 1 per cent. aqueous solution of osmic acid, and allow the slide to stand. This "fixes" the corpuscles without altering their shape. At the end of five minutes remove the excess of osmic acid with blotting-paper, add a drop of solution of picrocarmine and a trace of glycerine to prevent evaporation, and set aside for three or four hours (or even longer, as no overstaining takes place). At the end of this time the nucleus will be found to be stained red, and the perinuclear part homogeneous and yellow.

(2) *Picric Acid and Picrocarmine—Blood of a Newt or Frog.*—Place a drop of blood on a slide, and add a drop of a saturated solution of picric acid; put the slide aside and allow it to remain for five minutes, and at the end of that time, when the acid has "fixed" the corpuscles (that is, has coagulated their contents), the excess of acid should be removed by means of a narrow slip of blotting-paper. A drop of a solution of picrocarmine should now be added, and a trace of glycerine to prevent evaporation, and the preparation set aside for an hour. At the end of that time remove the picrocarmine solution by means of a slip of blotting-paper, and add a drop of Farrant's solution or glycerine, and apply a cover. The preparation may then be examined, when the perinuclear part of some of the corpuscles will be seen to be highly granular and of a deep yellow colour, while the nucleus is stained red. In some of the corpuscles there may also be seen delicate yellow-coloured threads, extending from the nucleus to the envelopes; in others, the perinuclear part remains uniformly homogeneous. This and the above preparation of blood-corpuscles can be preserved in glycerine.

The processes for *Yellow Elastic Tissue*, *Yellow Fibro-Cartilage*, *Fœtal Bone*, and the *Aorta* are also described.

* Journ. Anat. and Physiol., xv. (1881) pp. 349–54.

(3) *Picrocarmine and Logwood.*—Stain the sections first with picrocarmine, and after staining wash them in water slightly acidulated with acetic acid. Stain them with *dilute logwood* solution till they assume a lilac tint. Wash them, and mount in glycerine or dammar; the great point is to avoid overstaining the sections with the logwood. This method does very well for skin, scalp, developing bone, and the non-striped muscular fibres of the mesentery of the newt.

(4) *Picrocarmine and an Aniline Dye.*—Dr. Stirling has tried a great variety of the aniline dyes, but finds none of them so good, at least for gland tissue, as iodine green; it is used in the form of a 1 per cent. watery solution. Stain the tissue in picrocarmine, wash it in water acidulated with acetic acid, and then stain it in a solution of iodine green. This solution stains rapidly, and care must be taken not to overstain the tissue. Rapidly wash the section in water, and mount it in dammar. The section must not be left too long in spirit before cleaning it with clove-oil, because the spirit dissolves the green dye. Specimens doubly stained in this way have been preserved for many months, and students succeed in the process with the best results. Few methods yield such good results and are so instructive for the purpose of teaching. All preparations stained with iodine green must be mounted in dammar.

(5) *Picrocarmine and Iodine Green—Fœtal Cancellous Bone.*—Stain a section of the cancellated head of a fœtal bone in picrocarmine, and after washing it, stain it with iodine green and mount it in dammar. All the newly formed bone is red, but in the centre of each of the osseous trabeculæ the residue of the calcified cartilage on which bone is deposited is stained green. No method differentiates so clearly this marked difference in the constitution of these trabeculæ. Many of the bone corpuscles are stained green.

Ossifying Cuticular Cartilage, *Posterior part of the Tongue*, *Peyer's Patch*, *Solitary Glands*, *Trachea*, and *Bronchus* are also dealt with. In the case of the *Skin*, double stain a vertical section preferably from the sole of the foot of a fœtus. The cuticle and superficial layers of the epithelium are yellow, the stratum (rete) Malpighii is green, and one sees most admirably the continuation of these cells into the ducts of the sweat-glands, which are themselves green and form a marked contrast to the red-stained connective tissue of the cutis vera, through which they have to ascend to reach the surface. The outer layer of the grey matter of the *Cerebellum* with Purkinje's cells is, when double stained, red, while the inner or granular layer is green.

(6) *Logwood and Iodine Green* does best for the mucous glands of the tongue (green), while the serous glands take on the logwood stain.

(7) *Eosin and Iodine Green.*—Eosin is used as the ground colour. Stain the tissue in an alcoholic solution of eosin, which will stain it very rapidly, usually in a few seconds. Wash the section thoroughly in water acidulated with acetic or hydrochloric acid (1 per cent.), and then stain it with iodine green. This combination does very well for developing bone and for the cerebellum.

(8) *Eosin and Logwood.*—Here, again, eosin is the ground colour. This combination does very well for the cerebrum. Its general substance becomes stained with the eosin, while the logwood gives the nerve-cells a lilac or logwood tinge.

(9) *Gold Chloride and an Aniline Dye.*—Dr. Stirling corroborates Dr. H. Gibbes' views as to the value of this combination. The tissue must first be impregnated with gold chloride, and then stained with either aniline blue, iodine green, or a red dye such as rosein. The *tail of a young rat*, containing so many different structures, is an excellent material. Remove the skin from the tail, and place pieces one inch long into the juice of a fresh lemon for five minutes, and afterwards wash them to get rid of the acid. The fine tendons swell up under the action of the lemon-juice, and thus permit the more ready access of the gold chloride. Place the tissue for an hour or an hour and a half in a 1 per cent. solution of gold chloride; remove it and wash it thoroughly, and place it in a 25 per cent. solution of formic acid for twenty-four hours, which reduces the gold. During the process of reduction the tissue must be kept in the dark. The osseous tissue has then to be decalcified in the ordinary way, with a mixture of chromic acid and nitric acid. After it is decalcified preserve the tissue in alcohol. Transverse sections of the decalcified tail are made, and they may be stained with a red dye, such as an alcoholic solution of rosein, and afterwards with a watery solution of iodine green; mount them in dammar.

Preserving Confervæ and Desmids.*—The following solution has been found by P. Petit to be the best adapted for preserving the natural green colour of the chlorophyllian Algæ (Confervæ and Desmids), it having occurred to him that success might be attained by applying to Algæ the process made use of in commerce for preserving the green colour of vegetables.

The basis of the solution is "Ripart's fluid,"† and, by the addition of a copper salt, the tendency of that preparation to destroy the chlorophyll is overcome.

	gr.
Camphorated water	50·
Distilled water	50·
Crystallizable acetic acid	0·50
Crystallized chloride of copper	0·20
,, nitrate ,, ...	0·20

Dissolve and filter.

Preparations made in this liquid have preserved the brilliancy of their green hue, even after a year's exposure to the full daylight. *Spirogyra*, *Ulothrix*, and, above all, Desmids (*Penium Nægeli* and *Micrasterias crenulata*) have thus been preserved in all their freshness.

Preserving Marine Algæ.‡—Mr. C. J. Jones describes the following method which he adopts for preserving the colour of marine algæ.

* 'Brebissonia,' iii. (1880) p. 92.

† See Cornu and Rivet, 'Des Préparations microscopiques,' Paris, 1872.

‡ 'Northern Microscopist,' i. (1881) pp. 51–6.

The algæ are first washed in fresh water directly they are taken from the sea, to get rid of all sea-salts; they are then floated on to writing-paper, and dried by gentle pressure between sheets of white blotting-paper. When apparently dry, they are put between fresh blotting-paper and packed away in a dry place, where they must be kept perfectly free from the access of light.

When quite dry, cut off the number of pieces required and soak in *old* oil of cloves for a sufficient length of time to render them transparent, keeping them in the dark during the whole time. When soaked sufficiently, take them out of the oil and lay them upon clean white blotting-paper to absorb the excess, and mount in the ordinary way with cold balsam and benzol, on a cold slide, using a cold cover, and the result will be satisfactory. It is the operation of soaking the algæ in turpentine and the mounting in warm balsam that does the mischief, and it should not be forgotten that if the mounted slides are constantly exposed to the light they will bleach in time.

There are two points which should be noted: *old* oil of cloves must be used; the *new* is clear and of a very light yellow colour, while the old is more viscid and of a clear light brown. The other point is in the preparation of the balsam, that used in the foregoing preparations is at least thirteen years old, and most, if not all, the turpentine it originally contained has evaporated from it; it has been solid for years. The method adopted for bringing it into solution is to pour some benzol into the jar in which it is contained, and when sufficient has dissolved it is poured out into the bottle marked balsam and benzol. By this means only a thin layer of balsam is taken out each time, and having been exposed for a long time to the air it has lost the whole of its turpentine.

Soap for Preparing and Cleaning Diatoms.*—Professor Hamilton L. Smith writes as follows:—"Many persons who have faithfully tried the processes recommended in the books find, much to their disgust, that after all the trouble and care there will always be a large amount of flocculent matter, which neither acids nor burning will remove, and which will cause the diatoms to clot together and make the completed mount a rather dirty object to behold. Turning from their own preparations to those of Möller, and others who may have the secret, they know that there is somewhere a knowledge they do not possess and which has not yet crept into the books. And this is true. I was not myself aware of the remedy until long after I wrote the article which the editor of this journal copied from the 'Lens' into his little book entitled 'Diatoms.'

I have made it known to many, but, so far as I am informed, the process I am about to describe has not been published. I do not know whether 'Möller's secret' has leaked out, and so has reached me in the course of my extensive correspondence, for it is not my own invention, and indeed I cannot now remember just when or where it was first breathed to me, for I have known it for some years, but certainly with no 'injunction to secrecy.' I can assure the disgusted

* Amer. Journ. Micr., v. (1881) pp. 257–8.

student, who finds his beautiful diatoms—after all the acid treatment and all the incineration—yet full of flocculent matter, that there is a royal way to cleanness, and, after all, the good old way, by the use of soap! In fact, the use of this common and too much neglected article will produce astonishing changes in cleaning up the diatoms, as well as in cleansing dirty linen. I will describe what I did yesterday—the whole during one evening, and in fact, except for the waiting for the diatoms to settle, all the process would not occupy over ten minutes. I received a gathering of marine diatoms from the Hawaiian Islands, enclosed in a joint of bamboo instead of the usual vial. They were dried and matted, but the gathering was rich in the well-known Sandwich Island forms, so characteristic that I could have told the locality if I had not already known.

I put the dried material, such as it was, into a large test tube, and covered it well with nitric acid and left it for an hour (the time is not material). After this I boiled it, adding a little more acid, and, dropping in two small bits of bichromate of potassa, again boiled for a minute or two. The tube was now filled with rain water, and the whole mixed by inverting, &c. As soon as the mass (flocculent enough) had settled, the discoloured and acid water was poured off, and the tube was again filled with rain water (it is better to use soft water). After settling, the water was again poured off, and the deposit once more washed. So far this is the old method, which generally ends here, only washing out as best one can the lighter forms and broken frustules. A preparation made at this stage, marked (1) on the slide sent herewith, showed plenty of diatoms, principally *Synedra robusta* and *Rhabdonema mirificum*, but also any amount of the flocculent matter—the bane of diatom preparers, and which, from presence still of organic matter, browned in burning; a subsequent washing somewhat improved this—see specimen marked (2). Pouring off the supernatant water, and adding a little clean soft water, I now put into the tube a bit of common yellow soap, size of a pea, and again boiled the deposit for a minute or two, after which the tube was filled with clean rain water. Some fifteen or twenty minutes after, the yet milky fluid was poured off; it contained but few and very minute diatoms, which one can save, if so disposed, by keeping the poured-off fluid for a longer time. The tube, with a heavy deposit at bottom, was again filled with rain water and shaken, and now a peculiar brilliant sparkling and play of colours showed that the flocculent matter was gone, and only clean diatoms, sponge spicules, and possibly some sand remained. Specimen marked (3) shows appearance at this stage, and that marked (4) after one more washing. Finally, distilled water and alcohol was added; and after this washing, pouring off all the finer forms which remained in suspension after five minutes, and which were saved with those of the other washings, little else remained except clean diatoms, as shown on the finished slide sent herewith.

If, after this, any one exhibits a slide of diatoms full of flocculent and dirty deposit, peculiar to the old methods of treatment (unless, indeed, the original gathering had been an exceptionally clean one), we can only say, as in Miss Edgeworth's nursery story, 'What! no soap?' "

A caution was subsequently given,* which well deserves the attention of those who use soap. Many of the brands of soap contain notable quantities of silica in various forms. Even the fine toilet soaps contain it, the addition having been made for the purpose of increasing their detersive power; while to many of the more common kinds kaolin, silica, &c., are added merely for the purpose of increasing the weight. Therefore, in using soap, care must be taken not to use such as will introduce insoluble matter and even diatoms foreign to the original gathering.

It will be remembered that we have already given † an abstract of an article by Dr. H. Stolterfoth, describing his method of using soap for cleaning diatoms.

Mr. E. H. Griffiths endorses ‡ the use of soap with, if necessary, the subsequent use of nitric acid and carbonate of potash to bleach.

Mr. F. Kitton has also tried it § on a subpeat deposit and a recent fresh-water gathering from New Zealand, both of which, however, required acid treatment before being sufficiently clear for mounting. With Peruvian guano he found that the soap very much assisted in getting rid of a quantity of colouring matter, and materially reduced the amount of crude material. After pouring off all that did not subside in one hour he again boiled in soap and water, which further reduced the quantity, but the residue was totally unfit for mounting until further cleansed with nitric acid and chlorate of potash, and a final wash with liquor ammoniæ. On the marine deposits such as those from Virginia, California, Barbadoes, &c., soap seems to have but little if any effect.

To those who may be desirous of trying the soap process the following hints may be useful:—

1st. Carefully avoid hard water.

2nd. Use the best yellow soap (the ordinary soap often contains oil).

3rd. If soap is used after the acid, remove all traces of the latter with soft or distilled water.

4th. Dissolve the soap in the water and pour it on the material so as to make sure that no portion of it remains undissolved.

The soap process does not, in Mr. Kitton's opinion, possess any advantage over liquor ammoniæ in eliminating flocculent matter. The preliminary boiling in soap and water, by getting rid of a portion of the non-diatomaceous material, no doubt reduces the quantity of acid required, but it will not supersede the use of it.

Sullivant's Mechanical Fingers.||—Mr. J. Sullivant, of Ohio, has constructed mechanical fingers in two ways, which may be followed by any one desiring such an appliance and having a stage forceps only, or still better, a forceps and a nose-piece also.

* Amer. Journ. Micr., vi. (1881) p. 15.
† See this Journal, iii. (1880) p. 1034.
‡ Amer. Mon. Micr. Journ., ii. § Sci.-Gossip, 1881. pp. 102-3.
|| Amer. Mon. Micr. Journ., i. (1880) p. 186.

1. By taking a strip of pine wood, half an inch thick and of suitable length and breadth, and giving it a suitable shape, making a hole in the larger end of such size, that when lined with a bit of cloth, it fits tightly on and over the nose of an inch objective. In the smaller end another hole is to be made, into which a slightly tapering cork is pressed from above, in order to carry the forceps. Having fastened a bristle into the jaw of the stage-forceps by means of a drop of glue, and made a small hole for a guide, the shank of the forceps is forced into the cork and fastened in position with sealing-wax, and the finger is complete, with no expense but an hour's labour.

2. With still less labour, the nose-piece can be substituted for the above wooden carrier, screwing the cork into the nose-piece instead of the extra objective, and attaching the forceps as before.

In either case, the elasticity of the cork holds it in place with sufficient firmness to admit of its being rotated with finger and thumb, so as to move the point of the forceps with the bristle to the right or left as may be desired. The lifting of the object is done by means of the joint in the forceps.

Although these fingers may not be as perfect as those of more costly construction, yet combining as they do all movements essential to any finger, they may, the author considers, be used in an emergency, and in skilful hands will be found capable of effective work.

Mounting with Glycerin-jelly.*— Glycerin-jelly has long been known as a mounting medium, but most persons have found some difficulty in its use. The precipitation of balsam by all watery objects, especially aquatic insects and fresh-water algæ, induced Mr. W. H. Seaman to devise the following method of manipulation, by which glycerin-jelly may be used with great rapidity, avoiding the tedious preliminary preparation necessary for balsam :—

The jelly is made by dissolving transparent isinglass in sufficient water, so that it makes a stiff jelly when at the ordinary working temperature of the room where the slides are mounted, add one-tenth as much good glycerin and a little solution of borax, carbolic acid, or camphor-water. The mixture should be well filtered while hot through washed muslin or other fabric, as it will not run through the usual filter-paper, and the subsequent addition of a little alcohol improves its working. Objects, if perfectly clean, may be transferred at once from water to this medium, which should be slightly warmed before using, if not perfectly fluid. The cover is adjusted and the slide put away until a number have accumulated. The cover should not be pressed down too hard, and a liberal amount of jelly used to allow for shrinkage in drying. The slides may be finished as soon as the jelly has set, or they may be left for several days. If air bubbles are entangled they will usually escape while drying, or they may be driven out by warming the slide a little. When ready to finish the slides, take them to a water cooler and let the ice-cold water drip over them, while with a camel's-hair brush, rather stiff, all the superfluous jelly may be readily brushed away by the aid of the flowing

* Amer. Mon. Micr. Journ., ii. (1881) pp. 4–5.

water, which keeps the jelly under the cover hard. The slides are then dried with a towel or blotter, and finished with a balsam ring or any other cement desired.

The advantages of this method are that it obviates the necessity of the previous preparation of cells for objects of considerable thickness, and it seems to present most of the advantages of a fluid mount without its difficulties. If the slide is properly dried before finishing with balsam, no cloudiness appears, and the slide cannot be distinguished by inspection from a balsam mount, while there is much less distortion, loss of colour, &c., in the jelly than in the balsam solutions usually employed. Mr. Seaman has found no reason in ten years' experience to doubt that slides mounted in this way will be permanent.

Mounting Starches.*—The Editors of 'The Microscope'† describe their method of preserving starches as follows:—

"It is necessary first to have some aniline blue staining fluid, which we make after the formula given by Beale:—

Soluble aniline blue	$\frac{1}{2}$ grain.
Distilled water	1 ounce.
Alcohol	25 drops.

A mixture is made of equal parts of glycerine and water, to which is added a very little acetic acid, only two or three drops to the ounce.

To this mixture of slightly acidulated dilute glycerine is added the aniline blue staining fluid until the whole mixture is of a decided blue colour.

A drop of this mixture is placed on a glass slide and some of the starch to be mounted is dusted over the top. This dusting can be done to the very best advantage by touching the starch with a camel's-hair brush, and then slightly shaking the brush over the drop of coloured glycerine.

The starch soon sinks in the mixture, and the cover is applied. This method of dusting the starch is much better than stirring it in the mixture with a fine needle, which almost invariably results in an admixture of air.

After the cover is applied it is pressed down quite firmly against the slide, and all excess of the glycerine carefully removed. The slide is then transferred to the turntable, and a thin layer of dammar or balsam in benzole placed around the border of the cover. This soon hardens, and in a day or two we can finish with the white zinc or Brunswick black or other cements.

The effect of thus mounting the grains of starch is this:—the grains themselves have not taken the staining in the least, neither will they ever take it; they retain their natural appearance, surrounded everywhere by the blue glycerine, and the effect is most beautiful.

Specimens are in the Editor's possession that were mounted over a year ago in this way, and they are as perfect as the day they were prepared."

* 'The Microscope,' i. (1881) pp. 13–14.
† See this Journal, *infra*, p. 546.

Another plan is suggested * as an alternative to the ordinary one of placing a small quantity on the slide and then applying the balsam. Pour into a test-tube a sufficient quantity of Canada balsam to mount as many slides as may be required, and heat over the flame of a spirit lamp. When the balsam becomes thin, dredge into it through muslin the starch to be mounted. The air-bubbles must be burst either by again heating the balsam, or by diluting it with turpentine. The starch may then be mounted by taking up a small quantity with a dipping tube, and placing upon a glass slip, and covering with a thin circle or square previously warmed.

Mounting Desmids.†—Dr. M. C. Cooke, in dealing with the subject of mounting desmids for the Microscope, considers that the preservation of the endochrome and its colour is a matter of minor importance. For scientific purposes the empty frond is often of superior value to one filled with endochrome, as it permits the punctæ or markings of the segments to be seen, which are obliterated whilst the endochrome remains, and in the genus *Cosmarium* this is of greater importance than ever.

For the study of the endochrome alone its presence is of course most important; but this can be done, and drawings made from the plant in the living state, and if specimens can be mounted with the endochrome unchanged and uncontracted, so much the better, but no method has yet proved entirely satisfactory. Dr. Cooke kept some slides for twelve years mounted in silicates of potash and soda, but half of them deliquesced. Mr. Wills, however, kept slides much longer by simply using the water in which the Desmids were collected and never leaving them exposed to the daylight.

One great difficulty in mounting objects with such thin and delicate cell-walls as desmids is to employ a medium of no greater density than the cell-contents. If a denser medium, such as glycerine, be used, the endochrome immediately contracts, and never expands again as before. Water, or water containing a little camphor, is of equal density, and no change can be detected.

After all, the preservation of the endochrome is of less importance than the perfect contour of the cell. If there is any contraction or collapse, the objects are useless. Supposing, therefore, that there is no necessity to preserve the endochrome, there is another feature to remember besides the preservation of contour, and that is, that the medium employed should not render the delicate cell-walls so transparent as to become ultimately invisible. In simple water Dr. Cooke found no difficulty in discerning the structure of the cell-walls after a period of not less than twelve years. So much cannot be said for glycerine. Empty fronds, both of desmids and *Volvox*, stained of various colours, exhibit all the details in an unexceptionable manner.

Wax for Dry-mounting Opaque Objects.‡—Mr. H. J. Roper uses mahogany slides, 3 inches by 1 inch, with central circular cell

* Sci.-Gossip, 1881, p. 88.
† Journ. Quek. Micr. Club, vi. (1881) pp. 203–11 (4 pls.).
‡ Ibid., pp. 193–5.

pierced partially through the slide, leaving a "floor" of the wood, with sheets of wax, such as is used for making wax flowers (green and white).

To mount as an opaque object, say a portion of leaf with a parasitic fungus on it, cut a square, about an inch across, of the green wax, and lay it over the aperture in the slide; press it firmly down, and it will line the whole cell smoothly, and leave a margin of wax projecting round the upper surface. Having made sure that the leaf has no foreign matter on it, cut it so as to nicely fit the sunken cell, now lined with wax (if preferred leaving the wax showing all round), and a very slight pressure with the forefinger will ensure its adherence to the floor of wax, without in any way damaging the leaf or fungus; place the covering glass over the wax cell and press it firmly but gently down, then remove with the penknife all superfluous wax close to the edges of the covering glass; place over this the covering paper, not applying too much moisture round the central aperture, and the slide is complete.

It will sometimes happen that a slide is bored so deeply that it is necessary for the convenient illumination of the object that something more than one thickness of wax should be placed in the cell, so as to bring the object nearer to the covering glass; this can be taken advantage of to produce a very pretty effect. Before proceeding to line the cell with the wax, place an ordinary wafer in the bottom of it, moistening only the *lower* surface, choosing one, say, of a deep red colour; place over this a square of the white wax, which is always semi-transparent, and the result will be a delicate pink ground, well calculated to show up to advantage many opaque objects; other coloured wafers will produce at pleasure grounds of different tints, quite destitute of "glare" or "reflection," and soft and pleasing to the eye.

The advantages of this method, which is not new, except in slight but not unimportant modifications, are the unfailing certainty of the process, its celerity, total independence of turntables and varnishes, the lightness of the slides, the non-liability to breakage (for there is nothing frangible but the covering glass), and last, but not least, the permanence of the preparation. As to Professor Hamilton Smith's objection to wax cells on account of the covering glass becoming covered inside with a dew-like deposit, Mr. Roper has noticed this occasionally in specimens mounted on *glass* slides, but very rarely (not perhaps 1 per cent.) when mounted on *wooden* ones; and then no doubt the wax was used when too new, sufficient time not having been allowed for its volatile properties to evaporate; it is probable, too, that the wood itself may absorb the slight moisture which, in the case of the glass, can obtain no other refuge than the covering glass; at any rate, speaking from his own experience, he has found no inconvenience on this score, after mounting many hundreds of slides, extending over several years. The result of this very simple, quick, and easy process is, that the object is enclosed in a cell at once air-tight and water-tight, the adhesion of the wax to the wood, and the covering glass to the wax, strengthened by the adhesive cover paper, ensuring immunity from damp, while he has never known an instance in which any object was in the least affected by contact with the wax itself.

Wax Cells with White Zinc Cement for Fluid Mounts.—Mr. W. H. Walmsley, of Philadelphia, points out that while much has been written regarding the use of wax cells for dry mounts, their eminent adaptability for fluid mounts has been strangely overlooked. His own use of them for this purpose has extended over a considerable period of time, and has given great satisfaction. In the matter of economy, ease of preparation, and durability he considers the method adopted of considerable value. His chief reliance for the permanency of the cells rests upon the use of white zinc cement for coating the wax, the latter being mainly used for making the cells of various depths. Thirteen years' use of the white zinc cement, during which time he has prepared thousands of slides, has satisfied him of its entire permanence, while it is the most easily used of any cement, and its appearance is elegant on a finished slide. The only defect is that it turns yellow in time.

A ring of the cement is first made upon the slide with the turn-table. The wax ring is then added, and over the same successive coats of the cement are applied, allowing each to dry before another is added. After the last coat has been applied and the cell allowed to dry for some time, the cement becoming hard in about a day, or even less time, a thin coat of the cement is now applied, after which the cell is filled with the mounting fluid and the object is spread out and arranged properly in the cell. A thin glass cover must then be made to cover the cell in the usual manner, expelling the air, and it will adhere to the fresh cement all around. A spring clip is attached, the slide washed with clean water, using a camel's-hair pencil, then dried with a soft towel, when after a time another ring of the cement may be run around the cell, and the cell ornamented with coloured rings. The fluids used have been glycerine both pure and diluted, carbolic acid water, and Goadby's fluid.

Mr. Walmsley recently forwarded to the Society several slides which he had prepared and which appeared to be in every way excellent,* and he has communicated the formula which he now uses for preparing the cement as follows:—

One part (by weight) of mastic (tears) to 3 parts of gum dammar, dissolved in benzol. To 3 pints of this solution (about the consistency of cream) add 1 lb. of pure French oxide of zinc, ground in a small portion of linseed oil, and stir thoroughly. As the zinc will settle by standing it should be stirred every time it is used, and if it becomes too thick to flow readily, add a little benzol.

How to make Wax Cells.†—The wax cell seems to be in the peculiar position that, while some—even its originator—have discarded it, others declare that it is a valuable means of mounting objects. Dr. F. L. Bardeen, of Rochester, N.Y., writes as follows.

* See this Journal, *ante*, p. 147.

† Amer. Journ. Micr., vi. (1881) p. 48 (4 figs.). See Engl. Mech., xxxiii. (1881) p. 158.

"In view of its early brilliant promise, and present measure of success, would it not be well to try still further to rear it into full maturity? I now have about two dozen cells over a year old which are as good as when put up—not a flaw or sign whatever of moisture or condensation on the cover—no cracking, or cleaving from the slide. I have also sent at least three times as many to correspondents, mounted in the same way and at the same time, and as yet I have to hear of any going astray.

I do not know that there is anything essentially new in my method, or anything that others have not done; still one or two points I have not seen mentioned.

1st. I try to make the cell perfectly dry. This I do by *melting the wax as I make the cell*, also by drying the object and cover-glass and mounting as quickly as possible.

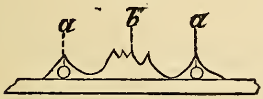
2nd. I hermetically seal the cell.

Concerning the first, I melt the wax as it is put on the slide, and also again as I shape it with the glass rod. I consider the melting as a very essential step in the process, as will be seen by the "sputtering" when melted and when remelted by the glass rod. The sputtering indicates moisture. The details are as follows:—

For deep cells I use brass rings to suit $\frac{5}{8}$-inch covers; for shallow cells one or two layers of tin-foil rings cut out with gun-punches. First cut from thin wax sheets two or three disks, and place on the slide—on the discs, place the ring (heated). Heat the slide till the wax melts. Some of it will run under the ring and form a wall outside the ring. Press the ring to the slide. Before it solidifies put it on a turntable and centre it. This will necessitate quick work on the non-self-centering table. It is best to prepare a number of slides thus far before the next step is taken.

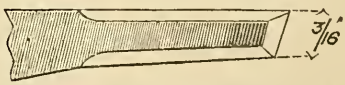
The cell is now half or two-thirds full, and level. Next take a glass rod 6 or 8 inches long and $\frac{3}{8}$ inch in diameter, round one end off in an alcohol flame, heat it hot enough to melt wax, and with the slide on the turntable make a depression all round the cell next the ring. This remelting and stirring as the table revolves, has the effect to still further displace any remaining air. Keep the table revolving until the rod is cold and the wax solid. The cell has now a raised ridge of wax on and at the inner edge of the ring, and a raised central part on which the object is to be mounted. (Fig. 130.)

FIG. 130.



Vertical section of cell. *a a*, cross section of ring; *b*, central portion.

FIG. 131.



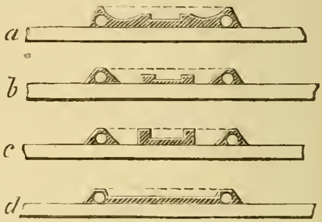
Bevelled turning tool, actual width at point $\frac{3}{16}$ inch.

Now with a turning tool (Fig. 131) made on the end of a small thin flat file or a similar piece of metal, turn the cell down as in Fig. 132. If the form of the object to be mounted permits, it can be fastened in place by simply touching the wax with the point of a hot wire. If the object is like globular sand or Polycystina, liable to roll about, a depression can be turned in the central part with slight containing

Fig. 132.

Central portion levelled off, also part over ring for cover.

Fig. 133.



walls. (Fig. 133, *a*, *b*, *c*.) If desired the central portion can be made as high as the outside, so that the cover will touch it when in place (*c*). If more room is needed, the whole cell may be made as at *d*.

I put the cover on as follows: Heat it enough to drive off all moisture, but not hot enough to melt the wax; lay it on the cell—retain it with a spring clip of *slight* pressure, and then hold it over the top of a lighted kerosene lamp just an instant. The pressure of the clip forces the cover into the melted wax and the cell is hermetically sealed.

Trim off on the turntable any surplus wax on the cover of the outside of the cell, and clean with a bit of cloth folded over the end of a small wedge-shaped piece of wood and dipped in alcohol.

Coat the cells and outer edge of the covers with Walmsley's zinc cement *first*, and put on black or coloured rings *after* it is dry. Cells that "run in"—at least, some of them—have had the Brunswick black put on first. This is wrong, for the turpentine is very penetrating, and should not be used until the zinc cement is quite dry.

This method gives all the beauty and mechanical perfection of lathe-work, and if due precaution is had in regard to the essential steps, will give, I believe, the best cell for opaque mounting."

Gutta-percha Cells.*—Dr. Phin has no faith in the durability of gutta-percha. Every specimen that he has had an opportunity of watching has become granular and brittle after a time. The finishing ring of cement which Professor Smith regards as unnecessary,† he considers the salvation of the cells. The gutta-percha ring, if unprotected, will, after a time, become a mere mass of loosely adherent grains. If, however, these grains be held together with shellac or some other varnish or cement, the cell may last a long time.

Apertures in Opaque Mountings.‡—Mr. C. C. Merriman recommends that a small opening should be left into the cells of opaque mountings, and gives the following directions for making it.

* Amer. Journ. Micr., v. (1880) p. 229.
† See this Journal, iii. (1880) p. 863.
‡ Amer. Journ. Micr., v. (1880) p. 253.

Whatever may be the material of which the cell is made, whether cement, or curtain ring, or hard rubber, file a little notch on the top of it, and on what will be the lower side of the slide, with a thin dentist's file, and large enough to lay a pin in the opening. Then, when the object is secured in the cell, moisten the rim of it, except in the notch, with Canada balsam. and apply the thin glass cover. After a day or two, balsam of the thickness of common syrup may be applied around the edge in such quantity, more or less, as one may fancy, care being taken to avoid the minute aperture. Or, if the balsam should happen by accident to run into the opening, it may be easily drawn out with a pin or needle applied a few times. With the point of a knife on the turntable, first push off any balsam that may be on the cover-glass, then gradually work it up on the slide until the edge of the mounting is a true slope or curve as may be desired.

Mr. Merriman uses for his own opaque mountings, cells made of bleached shellac cement and thoroughly dried. They are translucent, and therefore well adapted for the parabolic reflectors. The balsam in this case forms a beautiful finish, and there is no difficulty in applying it without interfering with the aperture. He does not regard wax cells as safe to use with any mountings, without first being covered with some cement, such as liquid marine glue, or gold size and dammar. If used for opaque mountings the notch should be cut in them before being covered with cement.

This device of leaving a minute aperture in the cells of opaque mountings has been tested for the past three years, and there has not been a failure in a single case that was owing to the mounting, while in hermetically closed cells there would be haziness, or the running of cement, or some trouble after a time with nearly half the specimens.

Copal Varnish.*—Mr. Deby finds this varnish dries very rapidly if slightly heated, or even if placed on a previously warmed slide. Dr. Van Heurck, of Antwerp, was the first to use it. The varnish to be used is what is called the "pale copal," and its consistency ought to be that of oil. It is much pleasanter to use than Canada balsam, does not make bubbles, and its refractive index is not very different from that of balsam, and does not interfere with the resolution of diatom markings. He has lately made many preparations in copal, dispensing with the cover-glass altogether. The drop of copal is placed on the diatoms and heated lightly over the spirit lamp. It soon takes the consistency of amber, and is hard enough to sustain wiping and brushing with a soft brush with impunity. The optical aberrations produced by the cover-glass are thus done away with.

Test for Illumination.†—Dr. Carl Seiler recommends blood-corpuscles as the best test for proper illumination. He says:—

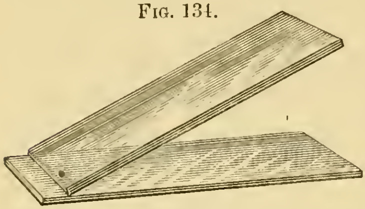
"In arranging our illuminating apparatus, we must have something to judge of the quality of the light as it passes through the Microscope; and it will be found that there is no better test than

* Journ. Quek. Micr. Club, vi. (1880) p. 167.

† 'Compendium of Microscopical Technology,' pp. 14, 15, 17.

a slide of blood, prepared in the following manner.* Take a clean 1 × 3 glass slide, and place near one end of it a drop of fresh blood obtained from the prick of a needle in the finger. Then take another slide with a ground edge, and place its edge into the drop of blood, inclining the second slide until it stands at an angle of about forty-five degrees towards the first one, and draw it quickly but evenly across the first slide (Fig. 134). The result will be that the blood-corpuscles are spread evenly upon the slide, in one layer only, thus giving an excellent view of their outline. The blood-corpuscles being lenticular bodies, with depressed centres, act like so many little lenses of glass, and show diffraction rings if the light is not properly arranged. It will, therefore, be seen that a slide prepared in this manner forms one of the best, if not *the* best, tests for illumination, as well as for flatness of field."

Fig. 134.



The author then describes the arrangement of lamp, bull's-eye condenser, concave mirror, and centering sub-stage condenser.

"When properly illuminated, the blood-corpuscles should appear as slightly olive-coloured disks, with a fine but intensely black outline, and on changing the focus there should appear a spot in the centre. In order to fully appreciate the importance of each one of the parts of the illuminating apparatus, and the necessity of having them in their proper position, let the student first remove the bull's-eye and let the light of the lamp alone fall upon the concave mirror, without change in anything else. He will then see that the outline of the blood-disks is much less sharply defined, and that there is a suspicion of another outline within the outer one. Let him then move the mirror bar slightly to the right or left of the median line, and he will find that this second outline will be more marked and a third one will be faintly seen, while the true margin of the corpuscle is far from being sharp. Let him, finally, remove the substage condenser from its proper position, or throw it out of centre, or take it off altogether, and he will find the blood-disks filled with rings and with a bright spot in the centre."

Microscopical Examination of Blood in the Diagnosis of Disease.†—For the purpose of these investigations, M. Hayem recommends the use of a cell thus constructed: a thick plane glass slide has a disk made on it of about 4 mm. in diameter; the rest of the slide is silvered; a small drop of blood is placed on the disk and is covered by a thin cover-glass, so that a layer of uniform thickness is obtained. A little saliva placed round the edge will prevent any evaporation.

When blood is treated with a mixture of 200 grammes of distilled water, one gramme of pure chloride of sodium, five grammes of sulphate

* The author describes himself as being indebted to Dr. J. J. Woodward for this plan of making an even blood slide.

† Comptes Rendus, xcii. (1881) p. 89.

of sodium, and half a gramme of pure bichloride of mercury, the blood-corpuscles are separately isolated and distinguished from the other constituents. The fibrine then breaks up into two distinct groups.

Perfectly normal blood, thus treated, shows the following reactions: At the moment when it coagulates it is traversed by a very delicate network of filaments. If at the moment of coagulation a reticulum of thick fibrillæ is seen, we may be sure that we have indications of an inflammatory lesion, and the modifications in the processes of coagulation are due to the extent and intensity of the inflammation. Pyrexia is not accompanied by any appreciable modification of the fibrine; but when fevers are complicated by inflammatory processes there are such modifications. In small-pox they only appear with the suppurating fever; in scarlet-fever and scarlatina the fibrine only augments at the period of desquamation. So again, in typhoid and intermittent fevers the so-called phlegmatic characters only appear when the disease is complicated by inflammation.

When cachectic conditions are not the results of chronic diseases, which bring about inflammatory lesions, the reticulum of the pure blood generally remains invisible, or is obscure, notwithstanding the unusual abundance of hæmatoblasts. Examination by the aid of the solution already described, shows, however, that the fibrine is allied; in advanced cases one often observes the so-called "plaques cachectiques," due to the infiltration of the hæmatoblasts by a finely granular substance, which points to a qualitative change in the characters of the fibrine.

Diatoms as Test Objects.*—L. Dippel publishes the result of observations on the value of certain diatoms as test objects for the Microscope, accompanied by exact measurements of the number of striæ.

The various forms of *Navicula rhomboides* are first discussed. The largest forms, called by the author var. *Lewisiana* (but quite distinct from the true and very interesting *N. Lewisiana*) has from 22 to 24 transverse striæ in 0·01 mm.; the ordinary *N. rhomboides* has 28 to 30; and the var. *saxonica* (*N. crassinervia* Brcb.) from 33 to 35 in 0·01 mm.

The true *Grammatophora subtilissima* Bailey occurs but rarely as a test object, and has 34–36 transverse striæ per 0·01 mm. *G. macilenta* W. Sm., which is usually supplied for it, has 25–28; *G. oceanica* Ehbg. 21–22; and *G. marina* 14–16 per 0·01 mm. The author describes *G. islandica* Ehbg. with 10–12; *G. serpentina*, with 17–18 transverse striæ per 0·01 mm.; the double structure of *G. gibberula*; and *G. robusta* Dippel, a new species with 14–16 transverse striæ per 0·01 mm. *G. tropica* Kg., to which *G. marina* Dippel also belongs, has 13·5–15·5 transverse striæ per 0·01 mm.; the true *G. marina* Lyngbye has 20·5–21. *G. marina* W. Sm. is one of the numerous intermediate forms between *G. tropica* Kg. and *G. marina* Lyngbye.

Nitzschia curvula has 35 36, *N. sigmatella* 26, and *N. sigma* 20-22 transverse striæ per 0·01 mm.

Drawings are given of all the forms described. It may be stated that all the drawings in Kützing's 'Bacillariceæ' are magnified only from 255 to 260, and not, as stated, 420 times.

* Zeitschr. f. Mikroskopi , ii. (1880) (4 pls.).

Examination of Metalliferous Clays.—Mr. M. Atwood, in a paper on the clays in the Comstock lode read before the San Francisco Microscopical Society, describes as follows the method of separating and examining the gold-bearing fragments :—

"The way in which I made the examination of the clays was, first, to place them in a porcelain dish, pouring hot water over and keeping them in the water for several hours, stirring occasionally till all the particles that would dissolve were taken up by the water. Afterwards I emptied the contents of the porcelain dish into a batéa, allowing everything that was dissolved to float away. By the batéa the pyritic matter and other heavy bodies were separated from the rest of the coarser, rounded, and lighter fragments of vein stuff and country rock. The pyritic matter is then tested for gold, silver, and tellurium, and also a microscopic examination of it is made under water. The fragments of country rock and vein stuff are then washed again, using a brush to rid them of any clay that might still adhere to them. After drying, they are put into a separator having sieves with 30, 50, and 100 holes to the linear inch, a uniform size enabling me to examine them better with the Microscope. The fragments that pass through the sieve having 100 holes I place in a small cell, fastened on the glass slide and filled with water, which I cover with thin glass. The shapes of the fragments are seen much better in this way, since, by slightly moving the thin glass cover, they can be made to turn and exhibit their forms in different directions."

Microscopic Tests for Poisons.*—Professor Rossbach has published, in the Vienna 'Klinische Wochenschrift,' some remarkably delicate tests for the presence of poisons when they are in too minute quantities to answer to any chemical tests.

As small animals, like frogs, mice, &c., are known to be very susceptible to the action of certain of the poisonous alkaloids, this fact is taken advantage of, and very weak solutions introduced into their circulation. Delicate as the tests are as applied to frogs, &c., Professor Rossbach gives far more delicate ones. A drop of water, containing infusoria, is placed on a glass slide and examined uncovered. The infusoria are examined carefully as to size, form, colour, &c.; then a drop of the solution is placed just at the edge of the fluid containing the infusoria. If organic poisons be present the infusoria are instantly destroyed, becoming a formless sediment. He says: "If a drop of water containing infusoria and weighing ·001 grain be used as a test, the quantity of strychnine required to cause remarkable changes will be ·00000006 of a grain. In this way $\frac{1}{15000000}$ of a grain of atropine can be detected." Thus, if the stomach of a person poisoned by strychnia contains a litre of fluid and only $\frac{3}{4}$ of a grain of the alkaloid, a single drop of this fluid will contain forty times as much strychnine as is necessary for the test.

Fine Rulings.—We recently referred † to "Fasoldt's Test Plate," which it was then claimed contained lines ruled at the rate of 1,000,000 to the inch.

* 'The Microscope,' i. (1881) p. 22. † See this Journal, iii. (1880) p. 891.

Dr. R. H. Ward, of Troy, N.Y., writes upon the subject as follows: *—

"In speaking of the modern microscopic rulings on glass, which have been regarded with so great and deserved an interest by all physicists, one cannot be too careful to discriminate fully between those that are known to be ruled and those whose ruling has been attempted but not yet demonstrated. It is self-evident that, in attempting to rule lines 5,000,000 to the inch, a band may be produced which does not consist of lines of that degree of fineness. There is no difficulty in arranging a machine to draw lines, theoretically, of any required degree of closeness. The register of a ruling engine can be so arranged and subdivided as to indicate a spacing at the ruling point of one ten-millionth of an inch as easily almost as of one-tenth of an inch; but it may well be doubted whether such fine motion is actually imparted to the diamond point, or could be recorded upon the surface of the glass. It is becoming common to hear the higher bands of Mr. Fasoldt, claiming up to 10,000,000 lines to the inch, spoken of as actually ruled, and only waiting an objective to reveal them. Such an error, made inadvertently by persons who would avoid it by a little reflection, as made in the last number of one of the most popular microscopical journals, gives a lasting as well as erroneous impression to non-scientific persons. Mr. Fasoldt's rulings are certainly remarkable, and the lower bands are ruled with great success; but how far up the scale they continue to be ruled as distinct lines is certainly at this time an undecided question."

Journal for Physical and Biological Instruments.—The 'Zeitschrift für Instrumentenkunde, Organ für Mittheilungen aus dem gesammten Gebiete der wissenschaftlichen Technik' † is a new journal, of large octavo size, devoted to instruments used in physical and biological science. The list of editors is headed by Professor E. Abbe, of Jena, the editor in chief being Dr. Georg Schwirkus. The journal occupies a new and important field, and will be of value to microscopists, as it contains a number of articles on microscopical and accessory instruments. Amongst the articles which have already appeared may be mentioned two on the construction and examination of micrometer screws, and on the illumination of micrometrical apparatus in Telescopes and Microscopes.

New Microscopical Journal.—A new illustrated bi-monthly Journal has appeared at Detroit, U.S.A., under the title of 'The Microscope and its Relation to Medicine and Pharmacy.' It is edited by Charles H. Stowell, M.D., Assistant Professor of Physiology and Histology, and Louisa R. Stowell, M.S., Assistant in Microscopical Botany in the University of Michigan.

The first number consists of thirty-two pages, with seven woodcuts, and contains amongst others the following articles:—"Ipecacuanha, its Structure and Adulterations;" "Membranous Dysmenorrhœa,

* Amer. Natural., xv. (1881) p. 259.

† 8vo., Berlin, 1881.

or False Mole;" "How to Mount the Starches;" eleven pages of "Editorial Abstracts" and "Selections," with a column of "Items" (which includes some medical "Facetiæ") and Reviews.

Seiler's Compendium of Microscopical Technology.*—The author of this book is Dr. Carl Seiler, late Director of the Microscopical and Biological section of the Academy of Natural Sciences of Philadelphia. The various chapters deal with (1) The Microscope and how to use it; (2) Preparation of animal tissues; (3) Cutting sections; (4) Staining of tissues; (5) Injecting the vascular system; (6) Mounting and finishing of specimens; (7) The preparation of vegetable tissues and insects; (8) Photomicrography; and an Appendix, containing a table of tumours.

The author's object has been (for the most part) not, as is so often the case, to describe a number of methods which have not been actually tried by the writer describing them, but to give a clear and short description of processes which he is in the habit of using himself, and which he has found to give uniformly satisfactory results.

Smith's 'How to See with the Microscope.'—This is a book of 410 pages and 33 figures (by Dr. J. Edwards Smith, a well-known American microscopist), a more extended notice of which must be deferred until later. In the meantime, we may mention that the leading idea which runs through the book is that of the superiority of wide-angled immersion-objectives, and it has been with peculiar interest that we have read Dr. Smith's remarks having regard to the recent revival of the old views of angular aperture. The author's remarks represent the state of our knowledge at a period which may be said to be half-way between the two extreme points—the period when no one supposed that wide-angled immersion-objectives could have any excess of aperture, in the proper sense of the term, over dry objectives, and that in which it was at last seen, not only that there *was* such an excess, but also how it acted.

Dr. Smith gives some very practical instances of the cases in which oil-immersion objectives exhibit a superiority of performance over all others, at the same time considering that the theoretical grounds for this superiority are beyond elucidation. As he puts it: "From a theoretical or mathematical standpoint, the study of balsam-"angles fairly bristles with difficulties; it has been to us a problem "to which our school-boy wrestlings with Euclid seem a pleasant "and simple exercise"—as indeed the question was to every one until Professor Abbe established not only the existence of the larger aperture, but also its specific function.

* Seiler, C., 'Compendium of Microscopical Technology; a Guide to Physicians and Students in the Use of the Microscope, and in the Preparation of Histological and Pathological Specimens.' 130 pp., 1 pl., and 16 figs. (8vo, Philadelphia, 1881.)

JOURNAL

OF THE

ROYAL MICROSCOPICAL SOCIETY;

CONTAINING ITS TRANSACTIONS AND PROCEEDINGS,

AND A SUMMARY OF CURRENT RESEARCHES RELATING TO

ZOOLOGY AND BOTANY

(principally Invertebrata and Cryptogamia),

MICROSCOPY, &c.

Edited by

FRANK CRISP, LL.B., B.A.,

One of the Secretaries of the Society
and a Vice-President and Treasurer of the Linnean Society of London;

WITH THE ASSISTANCE OF THE PUBLICATION COMMITTEE AND

A. W. BENNETT, M.A., B.Sc., *Lecturer on Botany at St. Thomas's Hospital,*

F. JEFFREY BELL, M.A., *Professor of Comparative Anatomy in King's College,*

S. O. RIDLEY, M.A., *of the British Museum,* AND JOHN MAYALL, JUN.,

FELLOWS OF THE SOCIETY.

Ser. II.—VOL. I. PART 2.

PUBLISHED FOR THE SOCIETY BY

WILLIAMS & NORGATE,

LONDON AND EDINBURGH.

1881.

diatoms in the gathering, but saw nothing of the sort except in the instances described. The *Naviculæ* were very lively, but he saw no examples of action upon foreign matter that came in their way. Neither could he detect any current, even along the *Nitzschias;* the motion of the gelatinous substance occurring only when it came in contact with the shell and apparently adhering to it.

The study of the diatom-shell has led the author to accept the opinion that the raphe is a real fissure in the shell, but in many species it is not a simple and vertical linear-opening of the shell. It is more like the joint formed by the overlapping of the edges of curved tiling on a roof: a thickened line of silica borders one lateral half of the shell, while the other half dips under it with a thin film. It is true that an osmotic force may be conceived as working along the raphe, as well as that a line of cilia should do so; but the difficulty is to account for such action upon an extraneous mass as that described, or to make osmosis from such a place upon the shell move the diatom in the direction of its length. The assumed presence or absence of a gelatinous film enveloping the diatom does not materially vary the conditions of the problem in either case. If we assume that the osmotic action is at the extremities of the shell, the observed phenomena, as to the action upon the gelatinous mass when in the middle of the frustule, are unaccounted for.

As to the manner in which the lapping of the halves of the frustule along the raphe is effected, it may be most easily seen in some of the coarser *Pleurosigma*. In broken shells of *P. attenuatum* and *P. formosum*, it was seen very plainly demonstrated. Sometimes the thickened line of silex which borders one-half of the frustule will be found sticking out alone, the thinner part of the shell being broken away from it. Sometimes it will be in its normal position, but the lateral halves of the shell will be separated by pressure, so as to show on one side the thick edge, and on the other the fitting gutter caused by the projection of a thin lip. Occasionally also a cross fracture of the shell will be found on a broken fragment, in such position that we get the benefit of a cross section, and see the whole joint in the form described.

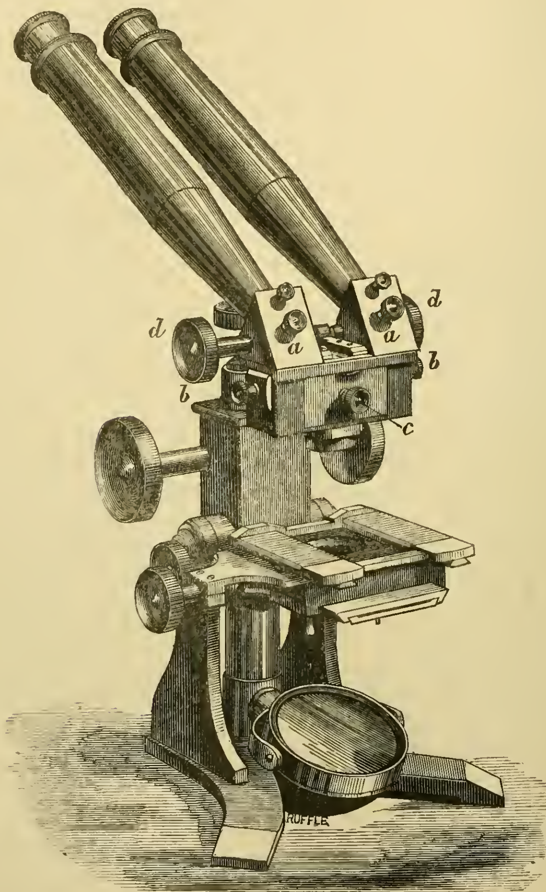
MICROSCOPY.

a. Instruments, Accessories, &c.

Ahrens's Erecting Binocular Microscope.—Fig. 135 shows a form of erecting binocular devised by Mr. C. D. Ahrens. The Microscope as figured is intended only for use with low powers, as there is no fine adjustment.

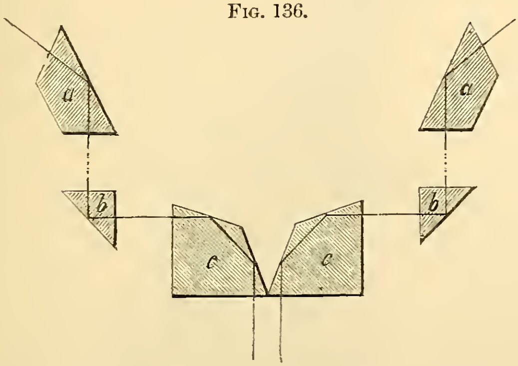
A sliding-box *c* contains two Wollaston prisms (such as are used for the *camera lucida*); *b b* are similar boxes containing each a right-angled prism; *a a* each contain a truncated equilateral prism that directs the image pencils up the respective inclined tubes; *d d* are milled heads acting on a pinion fitted with right- and left-handed screws working together, by which the body-tubes and *a a* can be set wider or closer to suit the distance of the observer's eyes.

Fig. 135.



The action of the prisms may be understood from the diagram (Fig. 136). *c c* are the two Wollaston prisms placed close together as figured, so that each may receive one-half of the pencil from the objective; by two internal reflections in each prism the rays are thrown into the right-angled prisms *b b*, from the long surfaces of which they are again totally reflected to total reflecting surfaces of the truncated equilateral prisms *a a*, and thence up the tubes. In the diagram *a a* are shown in vertical section, but in actual use in the Microscope, the reflecting surfaces, relatively to *b b*, would direct the rays from the vertical 60° backwards—that is to say the prisms *a a* are turned $\frac{1}{4}$ round on their bases in the diagram to show the direction of the rays. In future constructions, Mr. Ahrens thinks the prisms *a* and *b* should be cemented together.

FIG. 136.



We fear that this Microscope cannot compare with the simplicity of the Wenham and Stephenson models, or even with those which have been previously devised by Mr. Ahrens himself.

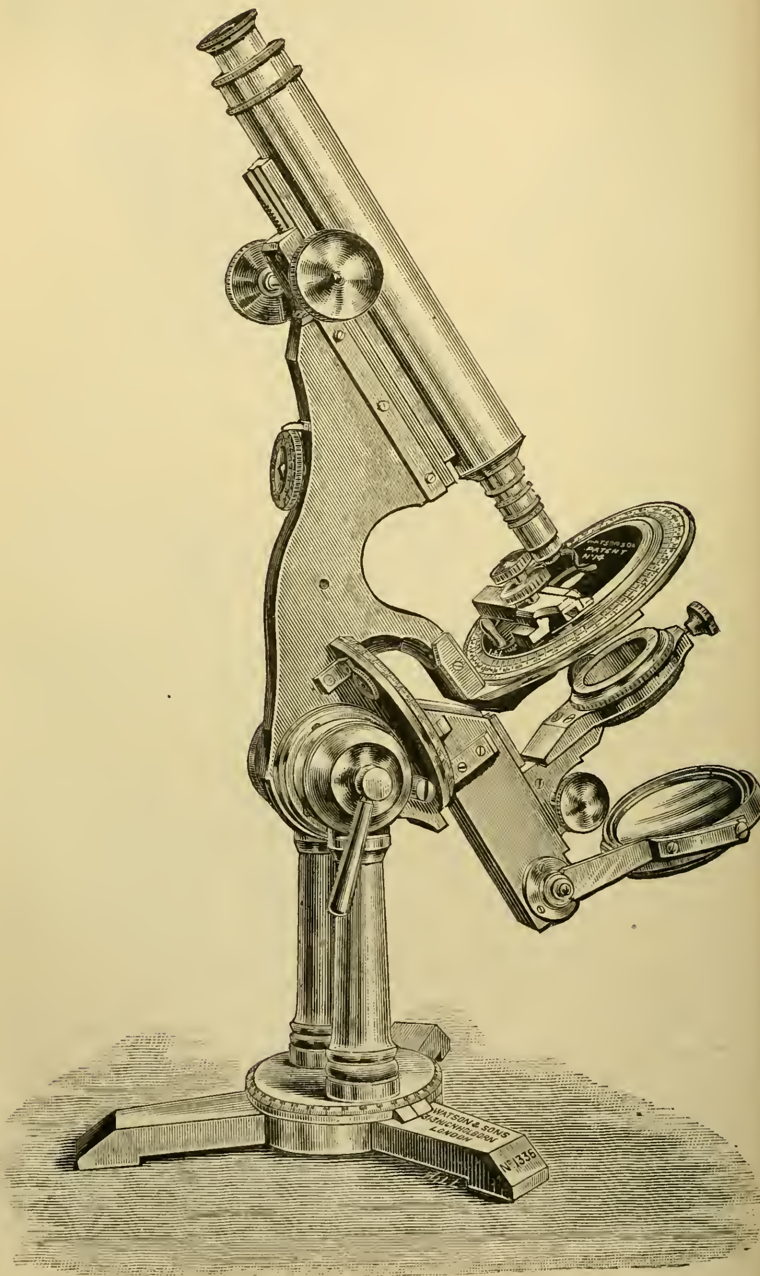
Crossley's Microscope with Special Arrangement for Illuminating the Swinging Substage.—This arrangement is the design of Mr. Edward Crossley, F.R.A.S. A general view of the Microscope, as constructed by Messrs. Watson, is given in Fig. 137, and Fig. 138 shows in section the prisms used for the illumination.

The light from the lamp is thrown into the hollow horizontal axis of the Microscope with the aid of the bull's-eye condenser, and by a prism placed in the centre of this axis, is reflected forwards in the direction of the axis on which the swinging substage turns. The arm of the swinging substage is made in the form of a box, and carries a second prism in the axis on which it moves, so as to intercept the rays of light coming from the first prism and reflect them in the direction of the arm or box. At the end of the box is a third prism, which throws the rays of light forward on to the mirror, by means of which they are finally directed to the object on the stage.

In Fig. 138, A is the first prism, as seen in vertical section in the centre of the horizontal axis. B is the second prism in the axis of the swinging substage. C is the third prism at the end of the box arm of the swinging substage. D is the mirror, and E is the stage carrying the object. The dotted line represents the direction taken by the rays from the lamp.

It will thus be seen that no change in position of the Microscope on its horizontal axis affects the direction of the light from the lamp, and also that whatever the position of the swinging substage, whether above or below the stage, the illumination remains constant upon

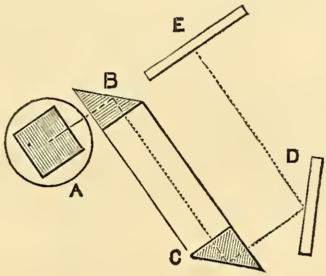
Fig. 137.



the object. Thus the greatest facility is given for illuminating the object at any angle, and seeing which is the most suitable.

The prisms used are 1 inch, and give sufficient light for a $\frac{1}{16}$-inch

FIG. 138.



object-glass with a Ross BB eye-piece, using of course a suitable condenser beneath the stage. The field of a 4-inch object-glass is also fully covered. It would be better to use prisms a quarter of an inch larger for the highest powers.

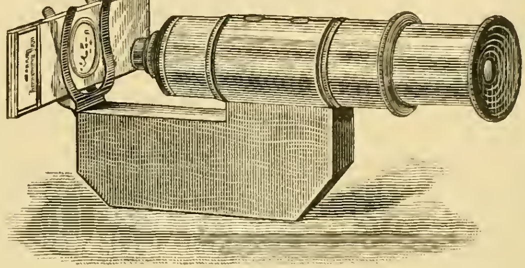
Griffith Club Microscope.—We gave a description and three figures of this Microscope on pp. 293–6, and have since received a communication from Mr. Griffith stating that sundry minor modifications have been made in the construction, which have improved the general steadiness of the movements.

The form of the tube carrying the stage has been changed by adding rectangular longitudinal flanges on opposite sides, modifying the corresponding fitting accordingly. A spiral spring has also been inserted, by which the bearings are kept in closer contact. These alterations give a smoother motion to the fine adjustment, and also provide more substantial support for the stage. The pin sliding in the spiral-grooved nut (by which the fine adjustment is effected) has been split and sprung, so that it now fills the cross-section of the groove, preventing lost motion and diminishing the lateral leverage that formerly obtained in moving the stage. The gauge of the optical-body has been enlarged to permit the use of eye-pieces of larger diameter. A movable wheel of diaphragms has also been added beneath the stage.

Parkes's Child's Portable Compound Microscope.—In this instrument (Fig. 139) the principle embodied in what are known as "demonstrating" Microscopes has been applied (by Messrs. Parkes) to a very cheap form of instrument sold (with a 2-inch object-glass, six objects, and two glass slips with hinge for temporary mounting) for a very few shillings.

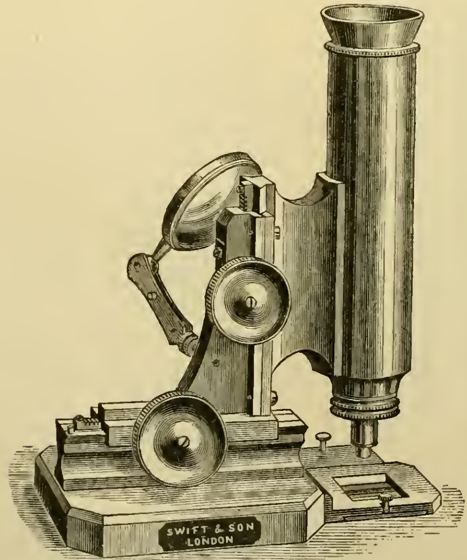
We are inclined to think that this form might advantageously be adopted in the case of more ambitious instruments, particularly those which are intended for field work.

Fig. 139.



Silk-Mercer's Microscope.—This instrument, for determining the quality of silk and other fabrics, is made by several opticians, the particular one shown in Fig. 140 being that issued by Messrs. Swift.

Fig. 140.



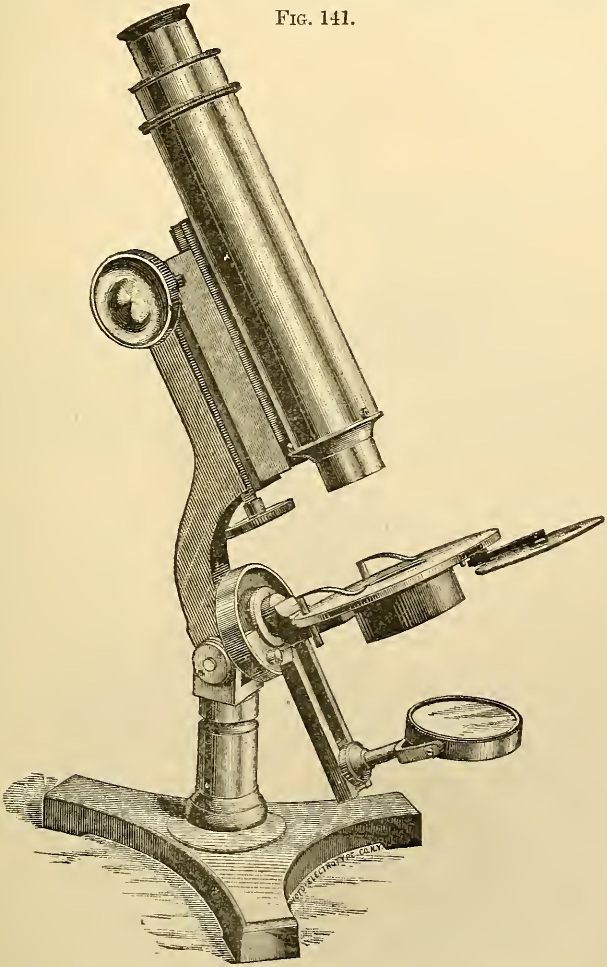
Its general form sufficiently appears from the figure. In addition to the usual rack-and-pinion focussing movement, the body can be moved from front to back and *vice versâ* by a second rack and pinion, lateral motion being obtained by shifting the whole instrument.

In the projecting piece in front of the base slides a lower plate, with two square openings of different sizes, which can be brought successively over the silk under investigation, so that, as with the ordinary "linen provers," areas of known extent may be under observation, and the number of strands to the metre or yard counted.

The eye-piece has a conical cap for shutting off extraneous light.

Sidle's No. 4 "Acme" Microscope.—Messrs. Sidle (U.S.A.) have brought out a still simpler Microscope than the one figured and

FIG. 141.

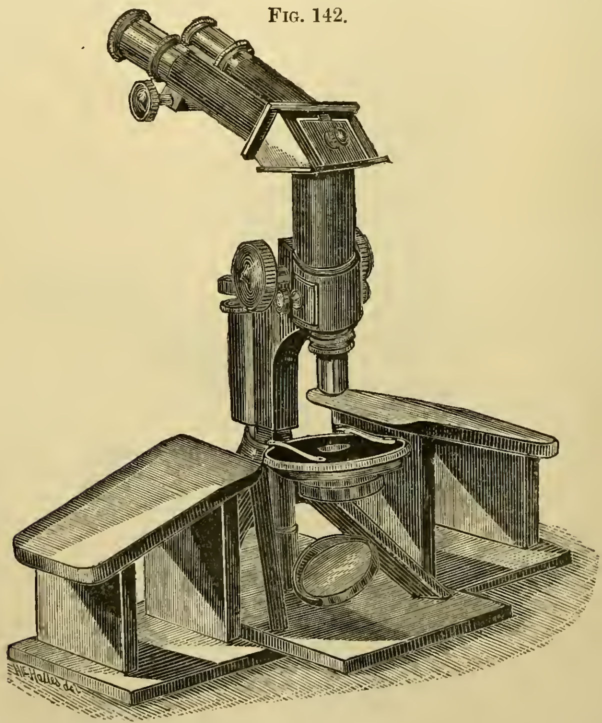


described in vol. iii. pp. 522–3, embodying the swinging substage with a minimum amount of "luxuries and intricate non-essentials."

The stand is shown in Fig. 141 (body $6\frac{1}{2}$ inches long and $1\frac{1}{3}$ inch diameter, and with a draw-tube). The fine adjustment moves the entire body by means of a micrometer-screw at the *lower* end, and within the bend of the limb, and is claimed to be "practically frictionless, acting on rollers, and perfectly free from lateral movement." The mirror slides upon a radial arm that swings laterally in a travelling zone in a metal disk, the centre of which is in the plane of the object. For opaque illumination the mirror-bar can be swung above the stage. The wheel of diaphragms fitting beneath the stage is mounted on a jointed arm allowing it to be turned aside clear of the stage opening, a fixed stop ensuring its being in the axial position when so required. The circular stage ($\frac{1}{8}$ inch thick), with standard screw in central opening, has spring clips, which may be used under the stage when great obliquity is required. A sliding substage to be attached to the mirror-bar can be substituted for the accessory tube.

Baker's Students' Stephenson's Erecting Binocular Microscope.—This instrument (Fig. 142) consists of the stand of the small

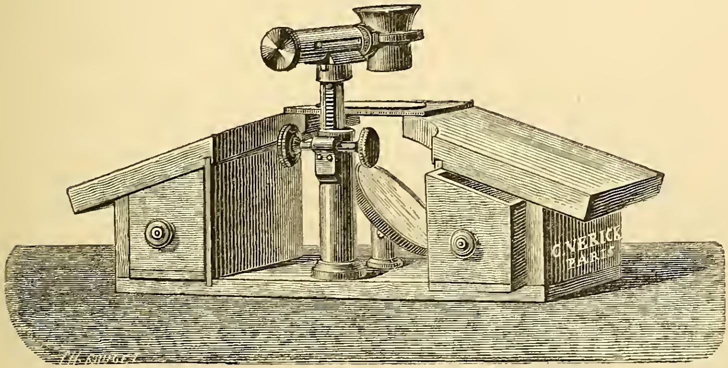
Fig. 142.



"Model Histological Microscope," to which is adapted the optical part of a "Stephenson's Erecting Binocular," the whole being placed in the centre of the base of a "Baker's Laboratory Dissecting Microscope" for giving the requisite support to the hands in dissecting on the stage. An ordinary monocular body can be readily substituted for the binocular when desired.

Vérick's Dissecting Microscope.—This instrument (Fig. 143) does not differ in a sufficiently marked manner from the usual form (though we have found it to be extremely conveniently arranged) to require it to be noticed here, but a special advantage to which we think attention may be usefully drawn is the mounting of the lenses, which are fixed in a tubular setting of more than ordinary depth and

FIG. 143.



expanded at the top to receive the eye—similar, in fact, to a watchmaker's glass. We are not able to say whether this additional depth would in prolonged examinations develope any disadvantages; but so far as we have had the opportunity of judging, it constitutes a specially effective protection to the eye from extraneous light beyond what is obtained in the case of the more ordinary setting.

Gundlach's "Periscopic" Eye-pieces.—We have been asked for a description of these eye-pieces, one of which was shown at a recent meeting of the Society. The following description is by Mr. Gundlach himself: *—

"The Huyghenian eye-piece in its original construction consists, as is well known, of two plano-convex lenses, of which one, the 'field-lens,' has three times the focal length of the other, the 'eye-lens'—the distance between the two being equal to double the focal length of the eye-lens, the plane side of the field-lens facing the convex side of the eye-lens.

"The field-lens not only widens the field of view, but also corrects the spherical as well as the chromatic aberration, as it is placed beyond the focal distance of the eye-lens (the actual eye-piece), and in consequence thereof acts negatively to the same.

* Appended to a Catalogue of Microscopes.

"This correction, however, is not a complete one; for, with the most favourable distance between the two lenses, a not inconsiderable remnant of the chromatic aberration still remains, while the spherical aberration is already correspondingly overcorrected. The first is noticeable by the blue edge bordering that side of the object which is turned towards the centre when the object is placed towards the edge of the field. The remnant of the spherical aberration causes the distortion and want of sharpness of definition at the edge of the field. By increasing the distance between field-lens and eye-lens the blue colour may indeed be made to disappear, but the spherical aberration increases correspondingly, and the field is narrowed considerably. If, on the contrary, the field-lens is brought closer to the eye-lens, the spherical aberration is certainly diminished; but, notwithstanding this, the image at the edge of the field does not become any more sharply defined, because the chromatic aberration has increased in equal ratio.

"One advantage, however, is gained by approaching the field-lens closer to the eye, namely, a considerable widening of the field.

"If, under these circumstances, the aberrations of the eye-lens are corrected by suitably composing the same of flint- and crown-glass, we have an eye-piece which, with all the advantages of the Huyghenian eye-piece, surpasses the latter by having a larger field.

"These facts form the basis of the construction of the Kellner orthoscopic eye-pieces. Kellner brought the field-lens into the focus of the eye-lens, made the latter achromatic, and chose such curvatures as to remove also the spherical aberration, and showing a flat field, for which latter purpose he also transformed the plane convex field-lens into a double convex one.

"The simultaneous accomplishment of all these results was favoured by the circumstance that in approaching in a Huyghenian eye-piece the field-lens to the eye-lens, the spherical aberration diminishes more rapidly than the chromatic. The preponderance of the latter over the former in the Huyghenian eye-piece must therefore admit of being equalized at a certain point, or rather must accommodate itself at this point to a similar disproportion in the achromatic eye-lens. This point, however, is, as in the Kellner eye-piece, almost exactly the focus of the eye-lens.

"A further approach of the field-lens to the eye-lens (bringing the latter within the focus of the former) again gives the preponderance to the chromatic aberration, and an equalization by an achromatic double lens becomes impossible under the circumstances.

"If, however, such further approach should be possible without such or other disadvantages, it would be very desirable, not only on account of the enlargement of the field which it would cause, but also the circumstance that when the field-lens is in the exact focus of the eye-lens, every fine particle of dust on the former is clearly visible and sharply defined, greatly interfering with the observation.

"These facts and considerations caused me to reflect whether a triple eye-lens (consisting of two positive crown-glass lenses, and one negative flint-glass lens) instead of a double lens would not better answer the conditions; and I have in consequence succeeded in forming such a lens, which answers the purpose in a very high degree.

"My new 'Periscopic eye-piece' consists of a triple eye-lens, a double convex field-lens, the latter being situated within the focal distance of the former, and a diaphragm, located in the focus, of the equivalent of both lenses.

"The field of the new eye-piece is considerably larger and flatter than that of Kellner's, and the image is sharply defined to the extreme edge.

"As the focus of the eye-piece lies behind the field-lens (the same as in Ramsden's eye-piece), it is particularly suitable for micrometers, especially as the divisions are distinctly, and in correct proportion, visible to the extreme edge, which is notably not the case with Ramsden's eye-piece.

"A micrometer division, placed in the focus of the eye-piece, shows, moreover, very perspicuously the high degree of the correction of the aberrations, while the image transmitted by an objective can be no reliable test, as the aberrations of the objective, especially the distortion, are easily confounded with those of the eye-piece."

Nachet's Objective Carrier.—Every working microscopist has desired a ready means of varying his objectives without the trouble of unscrewing one objective and screwing on another. This difficulty has been partly met by the use of the "nose-piece"; but this cannot be made conveniently (at least in the case of the heavily mounted English objectives) to carry more than two powers.*

Fig. 144.

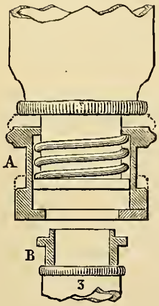
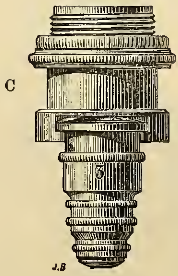


Fig. 145.



The attention of M. Nachet having been long directed to this point, he has recently brought out an improved form of his "porte-objectif" (originally made on a suggestion of Professor Thury) which allows the change of objectives to be readily made without as much raising of the body from the stage as is required in screwing and unscrewing.

It consists (Fig. 144) of a fixed inner cylinder, whose top screws into the bottom of the body, this being embraced by a movable outer

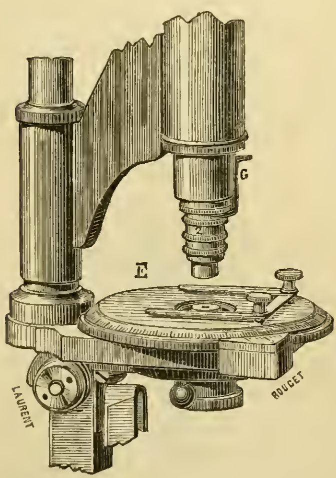
* See Carpenter's 'The Microscope, &c.,' 6th ed. (1881) pp. 856–7 (2 figs.).

cylinder A, that is kept closely pressed up to its lower end by a strong spiral spring between the two. The bottom of this outer cylinder is formed by a shoulder that is cut away for about one-fourth of its circumference, so as to allow a collar B, at the top of the objective to be slipped into the opening as shown at C (Fig. 145). When this is done, the objective is held firmly in place by the pressure of the spring; and all that is needed to remove it is a slight pulling down of the outer cylinder, which enables the collar of the objective to be slipped out again. The inner cylinder can have the Society screw; and the "collar" can be adapted to receive either M. Nachet's or any other objectives.

Having been enabled to make a trial of this little apparatus, Dr. Carpenter is "glad to be able to speak most favourably both of its simplicity and its effectiveness."

Vérick's Objective "Extractor."—This (Fig. 146) is also a contrivance for readily attaching and removing the objective, and which is in principle an adaptation of that of M. Nachet. The nose-piece (which screws into the body) has an outer tube somewhat shorter, to which is attached a semicircular "fork" projecting at right angles at the bottom. The outer tube is ordinarily pressed back by an internal spring, which brings the fork against the lower end of the nose-piece. On pressing the catch G which forms part of the outer tube, the latter descends, and the fork is separated from the nose-piece. The objective E, which has a wide collar, can then be slipped into the fork, and on releasing the tube the fork, with the objective, is drawn back by the spring. A short cylindrical piece projecting above the collar of the objective fits into a corresponding aperture at the end of the nose-piece, and thus secures accuracy of centering.

Fig. 146.



Whilst this apparatus undoubtedly allows a change of objectives to be made with the utmost rapidity, we find that the objectives are not retained in position with sufficient firmness, slight pressure being sufficient to deflect them laterally; this is especially noticeable in using an objective with "correction" collar.

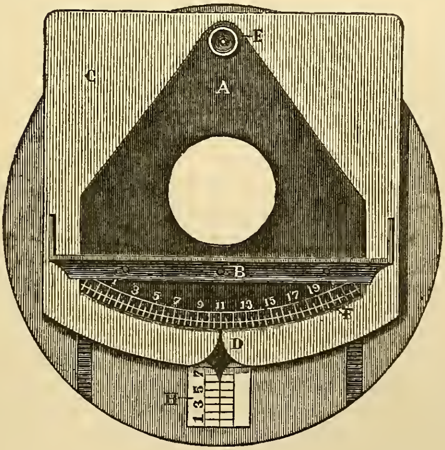
Sliding Objectives.—A modified method of accomplishing this object * is applied by Messrs. Parkes to a very cheap form of instrument. The end of the body-tube terminates with a smaller sprung

* See this Journal, iii. (1880) p. 1048.

tube about $\frac{3}{4}$ inch long and $\frac{1}{2}$ inch diameter, and into this the objectives (which are of correspondingly small size) slide direct. It is said that "by this plan the following important advantages are obtained: the object-glasses are more quickly and easily changed; the rack may be more uniformly worn by sliding them in at different distances; and should any portion of the rack be broken or deranged at the focussing points, the object-glass may still be used by sliding it in or out as may be required."

Smith's Object Plate and Finder.—The following note was read by Mr. James Smith at the May meeting of the Society:—"In the October number (1880) of the Journal of the Society, pp. 880–1, a very simple form of stage is described by Messrs. Schmidt and Haensch. It appeared to me that the use of a graduated arc for a finder was so effective that it might be easily and usefully applied to some English Microscopes; and in the following description and accompanying drawings, I have endeavoured to carry out the idea.

FIG. 147.



The only piece of apparatus required, where there is a good stage-plate (moving vertically) to which it can be applied, is a thin piece of metal somewhat of the shape A moving on a centre E by means of a small screw on the stage-plate; the bottom of the piece is cut into an arc of a circle, of which E is the centre, and upon this arc are graduated the divisions. Attached to this plate is an object-holder B. The only extra thickness interposed between the object and the source of illumination is that of the graduated plate (about $\frac{1}{30}$ of an inch). In the case of my own Microscope, where the stage-plate is not convenient for the purpose, the finder-plate is screwed to another thin plate C, as in the drawing, which slides vertically on the concentric stages. At the foot of this plate C is engraved or painted a small double pointer D, to read off the position of the graduated arc, and also the vertical divisions upon a small scale attached to or engraved upon the lower stage-plate H. This vertical scale can of course be placed in any other position either at the side or top of the stage; but I think the position I have indicated is the most convenient one.

In the case of a mechanical stage, the vertical screw movement could be used, the horizontal one being brought to a fixed position by means of a line marked upon it.

For use with a Microscope with a stage moving in all directions, my friend Mr. J. D. Hardy, of the Quekett Microscopical Club, has a small but ingenious addition to make this finder useable. In one of the small circular openings in which the stage-plate moves, he attaches a piece of metal G, Fig. 148, by means of a screw. This serves at once as a vertical scale and also makes the stage-plate move vertically in a fixed line, without which the finder could not be used.

Fig. 148.

The use of the finder is so obvious, I think, as to need scarcely any description. The object (say a slide of diatoms) is placed on the stage and moved about until any particular form is in the centre of the field; and the figures (say 11–7) are at once apparent and ready for record. By reading the intermediate spaces as 11·5–7·5, or nearer, great accuracy may be obtained; divisions of $\frac{1}{50}$ of an inch on the arc will represent $\frac{1}{100}$ or the $\frac{1}{150}$ on the slide according to the distance from the centre E. Objects under powers of 1000 or 2000 diameters may be centered with the utmost accuracy, and the exact stiffness in motion can at all times be given by the adjustment of the screw centre E.

In one of the German forms a racked arc worked by a milled head is used, when of course very great accuracy may be obtained; but for ordinary purposes I think this simple plate will be found to answer most required purposes, and it could be easily fitted to almost any form of Microscope. I do not make any comparison of this method of object-finding with any of the other ingenious appliances in use, but I think it will be found useful and perhaps applicable in some cases where other methods might not be so convenient. Except in the case of putting on a large trough, there is no need even to remove it, as it makes an agreeable working stage."

Wenham's Disk Illuminator.—Fig. 149 (natural size) shows a plan of mounting this disk,* devised by Mr. Wenham specially for Ross's improved Microscope. The disk is held between two small vertical plates attached to the cap of a cylinder that rotates by screwing into a metal ring fitting beneath the object-stage; it is thus entirely free of the substage and mirror, and when adjusted, forms part of the object-stage. The power of rotation (a most important element to develope the best effects with the device) is provided by the screw fitting, which also serves to adjust the disk at the required level for immersion contact with the base of the slide. The rotating-plate is suitably cut to allow a large angle of obliquity to the incident rays.

* See this Journal, iii. (1880) pp. 145–7.

Mr. T. Curties also devised a method of mounting the disk for use in the ordinary substage (Fig. 150—½ scale). A rod is made to slide in a small spring-tube in a substage fitting; and the disk is fixed to a short pin attached to an angle-piece at the top of the rod for convenience of centering, &c.

FIG. 149.

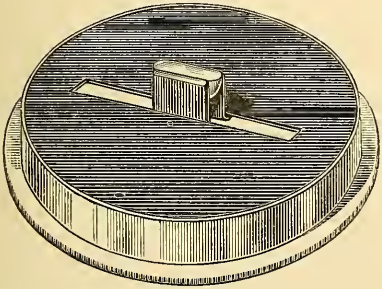
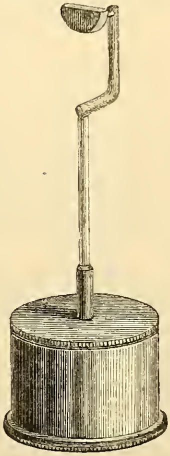


FIG. 150.



At a meeting of the Liverpool Microscopical Society last year, a very simple plan of mounting the disk was exhibited. A section of cork, about half an inch in thickness, was fitted to the stage opening beneath; and an aperture was cut in the cork suitably to hold the disk at the proper level and to allow free incidence of light.

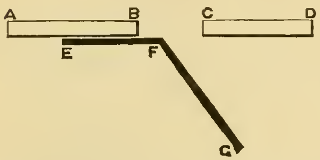
Smith's "V-shaped Diaphragm."—This was suggested by Dr. J. Edwards Smith in 1875 as of singular advantage in resolving severe tests, and he now says * that although in the interim a large variety of substage illuminators have been brought out, he still prefers it for "a *clean square* resolution of severe tests by oblique light." It consists simply of a piece of japanned iron plate (the ordinary "ferrotype" plate used by photographers) of say 3 inches square, which is fastened to the under side of the stage by one or more screws near its edge farthest from the mirror or lamp, and then bent down as shown in Fig. 151, the open side being adjacent to the source of illumination.

Dr. J. E. Blackham also records † his experience of the diaphragm for high angles, first pointing out that the name, V-shaped, is not well chosen, as the diaphragm itself is not V-shaped, but only forms one side of the V, the under side of the stage forming the other. "Of course, if the ferrotype plate is flat, it simply closes the well-

* Amer. Journ. Micr., vi. (1881) p. 59.
† Ibid., pp. 9–10 (3 figs.).

hole in the stage (and may thus be used for viewing opaque objects), but if one side of the plate is bent down, it leaves a wedge-shaped space between the plate and the under side of the stage, the apex of the wedge being toward the centre, and the base toward the outer edge of the stage. If the mirror be placed on the same side as the base of this wedge-shaped space, a beam of light can, upon swinging it out to a proper obliquity, be sent in upon the object, and no light less oblique can reach the object from below. As the ferrotype plate is perfectly pliable, it can be bent to any desired angle, and thus light of any desired degree of obliquity that the stage will admit can be obtained, quite free from any light of less obliquity.

Fig. 151.



A B C D is a section of the stage, E F G is the bent ferrotype plate forming the so-called V-diaphragm.

"With wide-angled lenses this has a remarkable effect in increasing the sharpness of resolution of fine-lined objects.

"With dry lenses of lesser angles the arrangement can be utilized to produce very fine dark-field effects, the diaphragm, in this case, being bent down *nearly* to the limit of the semi-aperture of the lens in use."

Dr. Blackham, in a previous article,* stated that with this single apparatus and a Tolles $\frac{1}{6}$ of 1·12 N. A. (= 95° balsam angle) he had frequently gone through the Möller balsam-mounted Probe-platte, resolving every diatom on it, using light from a common kerosene hand-lamp and concave mirror.

Value of Swinging Substages.—Considerable difference of opinion exists on this point, and the following is a statement of both sides of the question. The first seven paragraphs have been standing in type for some time, waiting for an opportunity for discussing the matter at one of the meetings of the Society.†

Mr. Grubb, in introducing his form of swinging substage to the Royal Irish Academy in 1853,‡ very clearly foresaw the advantage it would produce for oblique illumination. He dwelt particularly on "the power of directing the illuminating beam on the object at all angles of incidence . . . , and of registering the position at which peculiar effects are obtained." With Mr. Grubb's Microscope, however, the varying effects of obliquity of the illumination were obtained only by continued readjustment of the reflecting prism; the observer could not conveniently watch the effect of the changes in obliquity whilst actually making them—as with the Thury-Nachet traversing substage,§ which we regard as a very perfect realization of the advantages to be obtained by gradations of oblique illumination. The principle in this latter is indeed so good, that we hope to see it

* Amer. Journ. Micr., v. (1880) p. 44.
† See *infra*, p. 713.
‡ Proc. R. Irish Acad., v. (1853) pp. 296–7. See this Journal, iii. (1880) p. 1056.
§ See this Journal, iii. (1880) p. 1060.

applied on a larger sector-carriage, so that greater range of motion may be allowed for the condenser. For use with our most recent homogeneous-immersion objectives, the motion in arc of M. Nachet's condenser is too limited to develope the fullest power of their apertures. The only reason we can assign for the neglect with which Mr. Grubb's sector and M. Nachet's traversing substage were received by microscopists in general, is that in those early days so few objectives were produced with apertures large enough to be used effectively in conjunction with such apparatus.

The intention of all the swinging arrangements—both those above referred to and the others described at pp. 1060–80 of vol. iii. —is to provide oblique illumination up to the highest limit of transmitting power of aperture possessed by our objectives; also to provide "dark-field" illumination beyond this limit, or opaque illumination above the horizon of the object under examination—together with exact means of registering the inclination of the light, &c., so that the effects may be repeated again with certainty.

It has, however, been objected to the swinging substage that it is an unnecessary incumbrance, as there are various condensers which convert axial into obliquely incident light up to the utmost practical limits of obliquity. Of those recently constructed with special reference to "immersion" illumination, we may note the Abbe-Zeiss oil-immersion condenser, Powell and Lealand's two forms,* and Stephenson's catoptric immersion illuminator.† In all these devices diaphragms are arranged to exclude a portion of the centre of the pencil, and to allow more or less of the peripheral zone to be utilized, the range of action being still further increased by the eccentric and rotating motions of the substage in which they are used.

There can be no doubt that to a very large extent these condensers give effects of oblique illumination equal to those obtained with the swinging substage; but it must be remembered that the latter enables us to regulate the precise *angle and amount* of light that is most effectual with every variety of objects. No disposition of diaphragms has yet been applied to condensers used in the axial substage to enable us to regulate the *amount* of light without altering the *obliquity*. In this respect, therefore, we think the swinging substage is an advantageous addition to the Microscope. A further advantage is the facility with which, by its means, the *mirror* or a low-power condenser may be used above the stage for the illumination of opaque objects.

Many experiments conducted with a view to the determination of the most efficient means for obtaining oblique illumination have led us to value the plan suggested by Mr. Bulloch, of Chicago, U.S.A., as shown in Fig. 141 on p. 1078, vol. iii. (1880). Placing the microscope horizontally, with the lamp attached to the concentric swinging substage, a hemispherical lens in immersion contact with the base of

* See this Journal, iii. (1880) p. 147, and p. 330, where one is figured.
† Ibid., ii. (1879) p. 36.

the fluid-mounted slide, and using as a substage condenser a 2-inch objective with the lower half of the front lens covered up, we have been able to obtain with a minimum expenditure of time some of the most satisfactory images by oblique light that we have yet seen.

It may not be superfluous to remark that the most modern developments of high-power microscopy tend more and more to the prolonged and exhaustive examination and study of individual specimens under every variety of effects of light. Here again it must be acknowledged that the swinging substage proves of service by the rapidity with which the changes of illumination can be effected, and the certainty with which they can be recorded and repeated.

We do not here attempt to decide which special system of construction is most effectual. The question whether the radial arc originally devised by Grubb embodies the principle in the most practical form, is open to discussion,—and this applies equally to the Thury-Nachet device, the Zentmayer's swinging arm, or Tolles's traverse-lens.

Some discussion took place at the June meeting of the Society upon the preceding note, in which Mr. Crouch, Mr. Stephenson, and others took part.

Mr. Crouch said that in the early part of the year 1876 the swinging substage was re-introduced by an American firm of opticians, and exhibited at the Centennial Exhibition held in Philadelphia in that year as an improvement upon the various forms then in use. "As it was almost immediately adopted in this country, and has since, with some slight modifications, been applied by various makers, both here and in America, it has occurred to me that the time has arrived at which it is possible to ascertain what the advantages offered are (if any), and whether they are of sufficient importance to necessitate the remodelling of those stands usually fitted with the substage. At any rate, I think the discussion of this subject can only tend to the elucidation of facts which are of importance in the construction of the modern microscope-stand.

"The substage, it need scarcely be stated, is an addition made to the Microscope for the more ready application of the illuminating accessories applied beneath the object, practically comprising the polariscope, various dark-ground illuminators, and the achromatic and other condensers, either dry or on the immersion system. For the two first-named methods it is not suggested that a swinging substage is of any advantage. For immersion condensers, also, it cannot be of use, and its application is therefore limited to dry condensers of presumably small angle and comparatively long focus. Now, as the result of my own experience, and also that of all those whom I have had the privilege of consulting, this is found to be the most unsatisfactory and uncertain of all methods of obtaining an oblique illuminating pencil.

"It will at once be conceded that the proportion of objects for which this method of illumination is useful is exceedingly small, consisting mainly of a few of the diatomaceous tests, the resolution of the striation of which requires objectives of great aperture and high power. The immense majority of objects, however, shown by transmitted light require the use of objectives of lower aperture and power, ready means of applying the various accessories, and a firm stage with or without mechanical adjustments, giving a considerable range of motion.

"Now, since the introduction of the swinging substage, what do we find to be the tendency of the alterations either made or suggested? In the case of Microscopes provided with mechanical adjustments to the stage, a perilous attempt to reduce the thickness of the necessary plates and a serious limiting of the traversing movements with an increased complication of parts, which I can only look upon as a step backwards. For many years past the alterations made in the stand have all tended to a simplifying of construction and a consequent increase of strength, with less chance of derangement of the adjustments, and I cannot help thinking that we ought to be chary of making an addition which leads in the opposite direction, and which, as experience shows, only gives a result which can be better and more readily obtained by other means.

"I have only to add that I, with many others, shall be pleased to learn authoritatively whether anything has been done with the aid of this addition that has not been better done without it. I have the pleasure of the acquaintance of many possessors of Microscopes fitted with this adjunct, and as yet, with one exception, my inquiries have met with an answer unfavourable to it, the latest reply being that the owner had found it so inconvenient that he had made a fixture of it."

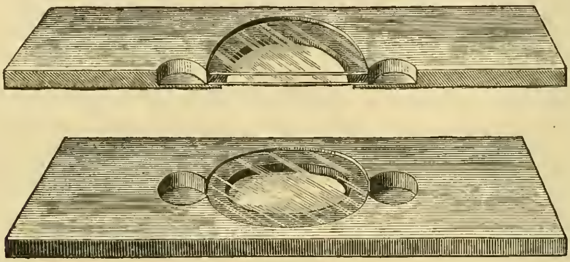
Mr. Stephenson said he concurred generally in the views expressed by Mr. Crouch.

It must always be borne in mind—and this was a matter of fact and not a matter of opinion—that objectives having apertures exceeding the equivalent of 180° in air could only be fully utilized by some immersion appliance (condenser or otherwise), and it was essential that this should give an aperture at least as great as that of the objective employed. A lens, or prism, must in every such case be attached to the slide by some immersion fluid of a refractive index equal to or exceeding the numerical aperture of the objective. Of course the swinging substage might support an independent condensing lens throwing light on the lens or prism attached to the slide, making an arrangement similar to the traverse lens of Tolles, which was much simpler; but, as the full aperture of every objective could be utilized without a swinging substage, he preferred the ordinary rigid form which was better adapted for axial illumination.

Botterill Life-slide.—The description of this slide (Fig. 152) should have accompanied that of the "Botterill Trough," given at p. 148 of the previous volume.

It consists of a brass slide 3 in. × 1 in., having a central opening of $\frac{3}{4}$ inch with a flange, upon which a circle of cover-glass is cemented, forming the bottom of a cell. A narrow ring of vulcanite, &c., shown in the figure, fits in the opening to provide (when required) depth for the object to be examined, and another cover-glass is put over this. Two small countersunk wells on either side communicate with the central cell, and enable the observer to remove or replenish the fluid. The advantages claimed for it are the facility with which it can be used and cleaned; its reversibility, allowing either side of the object to be examined through thin glass; the provision for renewing the supply of

FIG. 152.



water without disturbing any part of the apparatus, thus enabling objects to be kept under examination for an indefinite period; the same arrangement also allowing of the introduction of colouring matters, as carmine, indigo, &c.; and, lastly, its moderate cost and durability.

For Confervæ, small Infusoria, &c., it is sufficient to place the object on the bottom glass, with a drop of water, and apply the cover-glass in same manner as when using a glass stage-plate. When a thicker layer of water is required, the ring of vulcanite, cork, or other suitable material, of the requisite thickness, should be placed on the lower glass, and the object put in position, and the cover-glass applied as in mounting objects in liquid in a cell. The supply of water can be maintained by placing a drop occasionally in one of the side "wells," keeping the slide, when not under examination, in a small damp chamber, to prevent evaporation. To change the water, supply through one "well" and draw out through the other by means of blotting-paper.

Botterill's Life-trough.—Mr. Botterill objects* to the mode in which these troughs † are now made with *thick* glass. By using *thin* glass for both back and front a half-inch objective will focus up to the back of the trough, and higher powers, say up to the sixteenth immersion, can be used to examine objects on or near the front glass. Thin glass also allows a much better dark ground to be obtained with paraboloid or achromatic condenser.

With regard to the use of vulcanite, of which the troughs have been largely made,‡ Mr. Botterill prefers brass for general use and where marine organisms are not under examination, as brass allows thinner plates to be used and a flatter bevel consequently to be

* Sci.-Gossip, 1881, p. 160.
† For a description and figure, see this Journal, iii. (1880) p. 148.
‡ See this Journal, iii. (1880) p. 1082.

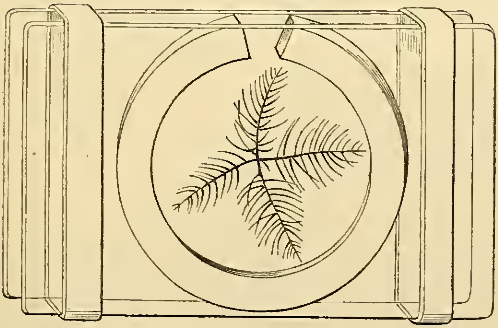
obtained, which is an advantage when higher powers than the one-inch are employed.

For keeping the glass apart, the "extra thick" indiarubber bands are the most generally useful, and in putting the trough together care must be taken to have the indiarubber and glass perfectly dry, as otherwise there is danger of a capillary leak.

Hardy's Vivarium.*—Mr. J. D. Hardy suggests a trough (or vivarium as he prefers to call it) which obviates the main objections to the old troughs, viz.:—(1) Their superfluous depth; (2) The necessity for taking out the object and bottling it if desired to carry it anywhere for exhibition; (3) The water in the trough (through its being open at the top) is always more or less susceptible to every movement, causing some objects to have a constantly oscillating motion; (4) Their non-reversibility; and (5) The necessity for keeping them upright.

The apparatus (Fig. 153) consists of two pieces of glass 3 in. × 2 in. or 2 inches square, to the lower of which is cemented an india-

Fig. 153.



rubber or glass ring of any desired thickness, and this is covered on the upper side with some adhesive substance or simply greased to render it impervious. A funnel-shaped piece about $\frac{1}{4}$ inch wide is cut out of the ring at the top and the upper plate put on the ring, and the whole held together by strong indiarubber rings or springs.

The object having been placed on the lower plate, the upper one is put on, and the cell filled up with water through the hole at the top. The apparatus is reversible, and it can be plunged into a beaker of water in any position without fear of losing the object.

In view of the difficulty of using thin glass for high powers which would not bear the pressure required to keep the cell water-tight, Mr. Ingpen suggests† the use of two semicircular clips so as to be exactly over the indiarubber ring.

Simple Growing-slide.‡—Mr. T. Charters White suggests a form of growing-slide which contains its own fluid, and may be left under

* Journ. Quek. Micr. Club, vi. (1881) pp. 212–3 (1 fig.).
† Ibid., pp. 224–5. ‡ Ibid., pp. 201–2.

the Microscope for an indefinite period and notes made of every change occurring from day to day.

A cell is built up to a suitable and convenient size of the strips of thick plate glass, to be got from any glass merchant, then cement a piece of the same plate glass in the centre of the cell with Canada balsam and we have a water-tight cell with a table of plate glass in the centre, the space round which can be half filled up with water. The object being placed on this table in water and covered with thin glass, the water in the trough will keep up any loss by evaporation without any saturation of the table. It must necessarily be used with the Microscope in a vertical position.

Wight's Growing-slide.* — Mr. W. H. Wight, of Baltimore, finding the supply of water in the older forms of growing-slide to be too limited and too soon exhausted, describes and recommends the following:—

A small hole is drilled near the margin of a concave slide, or near the centre of a plane one. Through this hole put a strand of cotton thread with one end in contact with the glass cover, the other immersed in a vessel containing the water, such as a soap dish, on which the slides can be rested. Thus there is perfect circulation and a large supply of water. The advantages of the plan are that it is inexpensive and the glass slip can readily be used as an ordinary slide, besides the opportunity always afforded of finding anything on the slide worth future study, and of immediately converting it into a growing-slide, thus avoiding the loss of rare objects.

In a convenient *résumé* of the growing-cells hitherto devised,† Dr. A. C. Stokes, having had Mr. Wight's slide in constant use for a month, finds it worthy of every consideration. A hole not more than $\frac{1}{32}$ inch in diameter, drilled by the sharpened shank of an old cataract-needle and a piece of Clark's No. 70 sewing cotton doubled and loosely twisted, have kept a deep cell abundantly supplied with water for many days, a channel being cut in the ring for the thread and another opposite to facilitate evaporation.

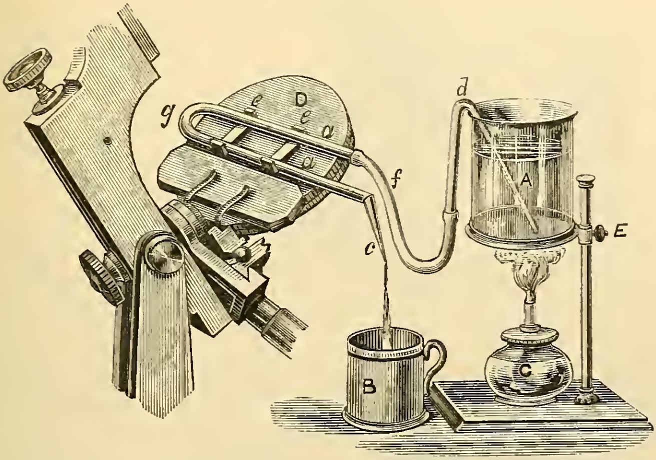
Bartley's Warm-stage.‡—Professor E. H. Bartley uses the apparatus illustrated in the accompanying sketch, which is claimed to be easy of construction, and to answer the purpose well.

It consists of a vessel of water A, which is supported on a tripod or a lamp-stand, and capable of being raised and lowered at will; the water in it is kept boiling when in use by the lamp C. A glass tube *a a*, about 6 mm. in diameter, and about 30 cm. long, is bent upon itself at *g*, so as to bring the two limbs parallel and within about 1·5 cm. of one another. One of the ends of this tube is then drawn off to a fine point, as shown at *c*, and is bent at an angle of 45° at a distance of 3 cm. from this end. The other limb of this tube is connected with the siphon tube *d*, by the rubber tube *f*. D is the stage of the Microscope, and *e e* are two pieces of cork which serve as

* Amer. Mon. Micr. Journ., ii. (1881) p. 23.
† Amer. Journ. Micr., vi. (1881) pp. 50–8 (18 figs.).
‡ Amer. Mon. Micr. Journ., i. (1880) pp. 181–2.

supports for the tube *a a* and as stops for the slide, and which may be cemented to the stage by mucilage, to make the apparatus more steady. These corks can be replaced by strips of sheet tin or brass, so bent as to serve the same purpose. The tube *a a* is placed in the usual position of the slide upon the stage, and the slide is placed

FIG. 154.



upon it; the light passes between the two limbs of the tube. The vessel B receives the water discharged at *c*. As long as the water in A is kept at 100° C., and a constant relation is maintained between the height of the water in this vessel and the stage, the temperature of the slide will remain constant as long as the water flows. By raising or lowering A, the velocity of the current of water may be increased or diminished, and the temperature of the slide is controlled.

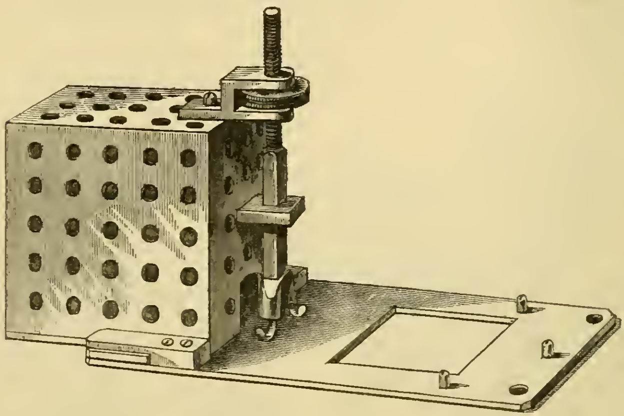
By a somewhat rough measurement of the temperature obtained with this apparatus, Professor Bartley finds it possible to procure a range of about 45° C., or from 27° C. to 70° C. As the normal temperature of the human body is 37° C., it will be seen that the range is all that is needed for the object for which it was intended. The higher temperatures are convenient for favouring chemical reactions under the Microscope, or for the evaporation of liquids, or other uses where a gentle heat and uniform temperature are desired.

Hume's Frog-plate.—Mr. A. Hume has devised the apparatus shown in Fig. 155,* for the greater convenience of the frog while under examination. To a plate of the ordinary form is attached (sliding in grooves) a brass box without a bottom, and pierced with apertures, in which the frog is placed, and in which it can freely

* See this Journal, iii. (1880) p. 174.

breathe. A clip shown at the end of the box can be screwed down by the milled head, more or less, so as to confine the frog's leg (which is

Fig. 155.



brought through the large hole shown in the box), the web of the foot being placed over the aperture of the plate, and examined in the usual way.

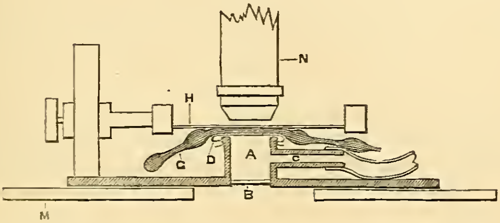
Apparatus for Investigating Capillary Blood-pressure (in the Frog's Foot).*—Drs. C. S. Roy and J. Graham-Brown describe the apparatus they employed in their investigations on this subject. Their observations were confined to tissues, the capillary circulation of which could be watched through the Microscope, the web of the frog being preferred, since it permits a study of the phenomena of the blood-flow through the minute vessels without interfering to any important extent with either the general or local circulation. To control the data obtained, however, most of the experiments were repeated on the tongue and mesentery of the frog, and on the tails of newts and small fishes. The principal facts learned were of such a nature as to leave little doubt of their general applicability to the peripheral circulation of warm-blooded animals.

In Fig. 156 is represented (somewhat diagrammatically) one of the arrangements which was finally found the most convenient. In the centre of a brass plate, measuring 10 cm. by 4·5 cm., is screwed the cylinder A (2·8 mm. internal diameter, and its upper edge 6 mm. above the plate), closed below by the glass plate B, the junction being air-tight. The upper outlet of the cylinder is closed by the delicate transparent membrane D, which presses upon the web, tongue, or other part examined, when the pressure of the air within the cylinder is raised. Counter-pressure is exerted by the thin glass plate H, which is so arranged that it can be fixed at any desired height above

* Journ. Physiol. (Foster), ii. (1880) pp. 325–30.

the cylinder. The part to be examined is placed between the cylinder and the glass plate, which is lowered as far as is possible without causing compression of the tissue between it and the edge of the cylinder; G represents the web seen in section, M is the stage of the Microscope, and N the objective.

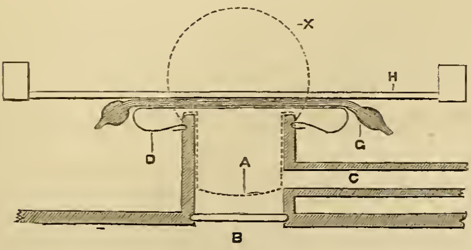
Fig. 156.



The membrane D must be sufficiently transparent to allow of the capillary circulation being seen clearly, even with high-power objectives. It must be flexible enough to transmit equally to the tissue examined the pressure of the air within the cylinder, and it must be as inelastic as possible, or, at all events, its elasticity coefficient (to use a convenient but scarcely accurate term) must be considerably greater than that of the tissue against which it presses, so that the latter may not be stretched to any important extent when the pressure in the cylinder is raised. The manner in which it is fastened on the cylinder must also be such that the pressure acting on that part of the web, &c., which lies within the field of the Microscope, i. e. the part lying in the centre of the area of contact between the web and membrane, will, when the instrument is arranged as in Fig. 156, be exactly equal to the pressure of the air within the chamber or cylinder A.

The first three of these conditions are fulfilled to perfection by the membrane which the author used from the peritoneum of the calf, and used by druggists for fastening the stoppers of perfume bottles (not to be confounded with the much thicker membrane also used for the same purpose).

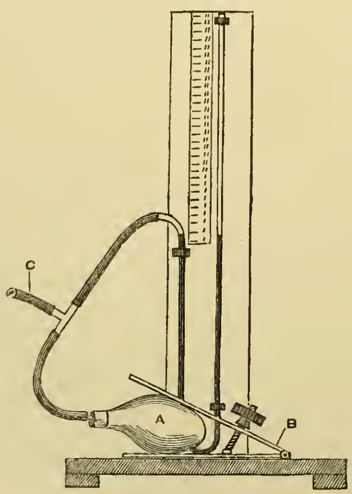
Fig. 157.



The manner in which the membrane must be fastened on the cylinder A, is illustrated by Fig. 157. A piece of the membrane having been moistened with water, is placed over the cylinder A, into which it is then pushed with the rounded end of a glass rod, so that it takes up the position represented in section by the dotted line. It is then securely tied by a thread resting in the groove cut for the purpose at the upper edge of the cylinder. On now raising the pressure within the chamber, by introducing air through the tube C, the membrane bulges out in the manner indicated by the line x. When, however, it is prevented from taking this position by the pressure of the glass plate H, or rather by the web, or other part, which is placed below the latter, it applies itself to this tissue, in the way represented by the line D.

The pressure of the air within the cylinder—that pressure to which the tissue lying within the field of the Microscope is subjected—is regulated by an arrangement which is illustrated by Fig. 158. The

Fig. 158.

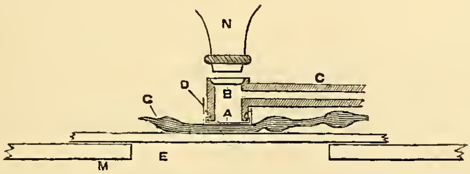


caoutchouc bag A containing air, can be compressed between the brass plates B, hinged together at one end, and which can be approximated by means of a screw. A T-tube connects the caoutchouc bag on the one hand with a water manometer, and on the other (C) with the cylinder A (in Figs. 156 and 157). In this way the pressure within the chamber can be regulated with the greatest nicety.

In the case of the web, care was at first taken that no part of any of the toes was included within the area to be compressed. It was afterwards found, however, that this precaution was unnecessary, the result of raising the pressure applied being the same so long as the part lying in the field was not too near one of the toes.

The modification illustrated by Fig. 159 was employed to prove that the pressure applied to the tissue in the centre of the compressed area is really that which is signified by the manometer. The little round chamber A, closed above by the glass plate B, and on the under end of which a membrane is fastened, is held by an appropriate holder immediately above the web, but not in contact with it. The

FIG. 159.



ordinary glass slide E, upon which the web G rests, serves to exert a counter-pressure. In order to prevent the membrane bulging out laterally, there is placed round the lower part of the cylinder, but not connected with it, a light ring of waxed paper, seen in section at D. The paper ring rests upon the web, and is so light that its presence has no appreciable influence on the circulation of the part.

In so far as the pressure is concerned, the authors have, with this arrangement, included a portion of web within a rigid box, closed below by the glass slide lying on the microscope-stage, above by the little glass plate B, and limited laterally by the cylinder and the ring of waxed paper, and the membrane. There is, at the same time, no interference with the entrance and exit of blood to and from the part of the web to be examined, other than that intentionally produced by raising the pressure within the chamber.

They made a number of careful experiments with this little apparatus, comparing the results obtained by its help, with those given by the simpler arrangement illustrated by Fig. 156, and are thoroughly convinced that, for any individual case, *cœteris paribus*, the arterioles and capillaries of a given part are made to collapse at the same pressure with both methods. It is not pretended, of course, that, with the arrangement represented in Fig. 156, the pressure on the web is equal over the whole area of contact between it and the membrane. Doubtless, at the edge of this area, the pressure applied will be somewhat less than it is at the centre. It is only the central part, however, which can come within the field, and for this part, as already mentioned, the pressure which acts upon the tissue is correctly indicated by the manometer.

The frogs used (*R. esc.* as well as *R. temp.*, and the greater number winter frogs) were for the most part uncurarized, as the blood-pressure of curarized animals is liable to variations which do not occur in the case of uncurarized animals. It was found that it is very easy so to fasten a frog upon an appropriate holder, that, while the foot and body are kept fixed, the general circulation is little or not at all interfered with. The animal may be kept under observation with the Microscope for many hours, without the slightest fall in the blood-pressure resulting.

As the greatest care in attending to details is necessary in investigations such as those in question here, the manner employed for fastening the frogs for examination may be explained. Through the narrow slip of wood upon which the animal rests are cut, near one of its ends, two large holes to allow the passage of the piece of tape which is used to fix the four limbs. The circulation through these is necessarily interfered with to some extent by their being so held, but this it is scarcely possible to avoid without curarizing the animal, and thereby introducing a more serious cause of error. One web having been spread out and fixed by threads to the forked extremity of the holder, the other leg is bent upon itself, as when it is drawn up voluntarily by the animal, in which position it is held by a tape passing loosely round it. It is not difficult so to arrange the tape that it will only press upon the leg when extension is attempted. The leg corresponding to the web which is to be examined is prevented from being drawn up by means of pins stuck into the wood on each side of it. These are placed so that, while they effectually prevent the least flexion, they do not press upon the limb when the latter is at rest. Usually one was placed on the inner side of the ankle, a second on the outer aspect of the knee, and a third on the opposite side of the body close to the pelvis. These are stuck somewhat obliquely into the wood, so that they overhang the part next them, and prevent the leg being raised from the board. In these circumstances frogs will often remain quite motionless for many hours, in a condition more or less closely resembling the so-called "magnetized" state, which can be so readily induced in birds and some other animals.

When the tongue or mesentery was examined the frogs were curarized. For studying the pressure in the vessels of the tail of the fish, a small trough, similar in principle to that recommended by Caton, was used, and in this case an arrangement such as that illustrated by Fig. 159, but without the paper ring, was employed.

Rogers' Micrometers.—Prof. W. A. Rogers, of Cambridge, U.S.A. (a Fellow of this Society), having completed his dividing engine, which has been three years in construction, at a cost of $4000, is willing to furnish standard micrometers without cost to any competent person who will make a careful study of the subdivisions, and who will at the same time agree to publish the results, without communication with him; and in order to meet a small portion of the expense incurred in the construction of the machine, he is also prepared to make standards, guaranteed to be aliquot parts, either of the British imperial yard "Bronze 1," or of the "Mètre des Archives."

At present Prof. Rogers will make the following patterns:—

1. 101 lines ·001 inch, and 101 lines ·001 cm. with the first line in each common to both.
2. 301 lines, 100 coarse, 100 very fine, for high powers, 101 coarse, all ·01 mm.

3. 501 lines ·01 mm., and 501 lines $\frac{1}{2500}$ inch.
4. 1001 lines ·01 mm., and 1001 lines $\frac{1}{2500}$ inch.
5. The same as the preceding one, but with both sets of lines double; that is, ruled both with fine and with coarse lines. In all the above, the 5th and 10th lines are longer than the others.

The object in ruling the lines $\frac{1}{2500}$ of an inch apart is to permit of ready comparison with the ·001 mm. lines, these spaces being approximately equal. It will be seen that one band acts as a vernier to the other.

The extreme working length of the screw of the machine is half a metre. The theoretical limit of subdivision is about two billionths of a centimetre. The practical limit may be set at about one fifty-thousandth of a centimetre.

Ideal Series of Objectives for Microscopical Work.*—Governor S. D. Cox, of Cincinnati, suggests the following as what might fairly be called an ideal series of lenses:—

"(1) An objective of 40° aperture and half an inch working distance, giving about 40 diameters magnification with the ordinary No. 1 ocular, and resolving 38,000 lines to the inch. (2) An objective of 100° aperture and one-eighth of an inch working distance, giving about 120 diameters, and resolving 70,000 lines to the inch. (3) A homogeneous-immersion objective of 120° balsam-angle of aperture, giving about 300 diameters, and resolving 120,000 lines to the inch. Proper eye-pieces would make these three objectives cover the intermediate magnifications desirable, and the third objective in the list would resolve any test resolved by any glass yet made and in the market, whilst the 40° glass would give all the 'penetration' needed for the binocular with opaque objects."

Dr. J. Edwards Smith also recommends † the following series of objectives as best fitted for microscopical work chosen from the standpoint of a protracted experience "over the tube":—

First, a $\frac{2}{3}$-inch, aperture 45° to 47°, having a working distance of $\frac{1}{4}$ inch, thus suitable for wet mounts without covers, and resolving 35,000 to 40,000 lines. This comes tolerably close to the ideal inch of 40°, both as to resolving power and working distance.

Second, a "real good honest" $\frac{1}{2}$ inch of 40°, recommended as a "hack" and for work over acids, &c.

Third, a first-class wide-angled duplex objective, say a $\frac{1}{6}$ or a $\frac{1}{10}$, resolving all the most difficult tests.

High Amplifications. ‡—Referring to the note at pp. 127–9 of this volume, Dr. Phin disclaims the idea of being an advocate for excessive amplifications; on the contrary, he has always opposed their use. "It "is now pretty well recognized that very high-power objectives do not "reveal anything more than those of moderate power, it being assumed

* 'Cincinnati Medical News,' Jan. 1881.
† Amer. Journ. Micr., vi. (1881) pp. 66–7.
‡ Ibid., p. 64.

"that the latter are of first-rate quality and used with high eye-pieces, "and the question comes up, 'How high may the eye-piece be?' Our "own impression is, that the same circumstances which prevent the "successful construction of high objectives will prevent the construc-"tion and employment of high eye-pieces. Just where the limit lies "it may be difficult to state, but we doubt the efficacy of any eye-piece "higher than a one-eight. This, with an objective of one-tenth would "give 8000 to 10,000 diameters, and this seems to be about the limit "arrived at by our best workers."

Conditions of Microstereoscopic Vision—"Penetration."—It is well known that, although binocular Microscopes have been devised which allow the use of high powers, there is always a very marked falling off in the *stereoscopic* effect. Several unsuccessful attempts have hitherto been made to elucidate this on theoretical grounds. Professor Abbe has, however, now published * an elaborate discussion of the conditions of microstereoscopic vision which clears away the difficulties which have attended the previous considerations of the subject.

In an introductory part he points out that the stereoscopic effect of binocular observation in the Microscope is fettered by restrictions which are not in any way caused by the action of the particular stereoscopic apparatus, but arise from the general laws of microscopic vision. The *direct* appreciation of solid forms in binocular vision obviously cannot extend further than the delineation of them goes. It is only when an object can be *seen* in all its parts in *one* field of the Microscope (that is, under one focussing) that a true stereoscopic image of it is obtained. So long as only a small part of the object is visible *simultaneously* with any distinctness, no stereoscopic apparatus, however perfect, can bring into view the form of the whole. Now as the amplification is increased the Microscope continually loses in *depth*, and this decrease in depth (starting with the lowest powers) is not simply proportional to the amplification, but is in a very much greater ratio. Thus with an amplification of 300, the depth is not the $\frac{1}{10}$th of that with 30 times, but about the $\frac{1}{50}$th only, so that an entirely *disproportional* loss of depth takes place, and it is only when we pass beyond the medium powers that the further decrease becomes approximately proportional to the amplification. But already with an amplification of not more than 300 times the absolute depth of the image scarcely amounts to the hundredth of a millimetre, and with 1000 times not even to a micromillimetre. The thickness of the object which can be seen in *one* field of the Microscope therefore decreases more and more with increase of amplification, at first (commencing from the lowest powers) very rapidly, and not in a less degree until the depth of vision has become very small. The scope for stereoscopic observation must always be restricted in the same ratio. Only under relatively low amplifications is a direct solid view of those objects possible whose depth is a considerable fraction

* Zeitschr. f. Mikr., ii. (1880) p. 207.

of the diameter of the field. Even with medium powers of 200–300 only very thin objects can be seen in relief, and with high powers we are confined to objects, the depth of which does not exceed a few micromillimetres.

It is seen, therefore, that fairly satisfactory stereoscopic observation cannot be extended in general beyond moderate amplifications, not even when the binocular apparatus allows the use of high powers. As soon as these become necessary stereoscopic perception is limited to objects of so little depth that a plastic view of them can hardly be productive of any scientific advantage, although effective images are still possible with *suitable* objects. It follows therefore, that in regard to the more difficult problems of microscopical observation, any substantial aid by means of binocular vision is necessarily precluded.

The following is a full translation of Professor Abbe's paper so far as it relates to the theoretical question, with, however, some modifications and additions by himself:—

The questions which relate to *depth*-perspective or visual *space* (as distinguished from *field*) in microscopical vision have never hitherto been elucidated, though their solution constitutes the data for a proper notion of the conditions of micro-*stereoscopic* vision.

The delineation of *solid* objects by a system of lenses is, by virtue of the most general laws of optical delineation, subject to a peculiar disproportion in amplification. The linear amplification of the *depth*-dimension (parallel to the axis of the optical system) is when object and image are in the same medium, always equal to the *square* of the linear amplification of the dimensions at right angles to the axis; and if the object is in a more highly refracting medium than air, it is equal to this square divided by the refractive index of the medium. In every case, therefore, it will be found that in proportion to the lateral amplification there is a progressive and with high powers a rapidly increasing *over-amplification* of the depth of the three-dimensional image. When, for example, a particular transverse section of the object is magnified 100 times in breadth, the distance between the planes of parts lying one behind the other is magnified 10,000 times, at the corresponding points on the axis, when the object is in air, 7500 times when it is in water, and still as much as 6600 times when it is in Canada balsam.

The excessive distortion above described with high amplifications would not, however, *of itself* so much hinder the correct appreciation of solid forms in the microscopical image as might appear at first sight. For by virtue of the geometrical character of optical image-formation, the solid image maintains a correct perspective in spite of the over-amplification of the one dimension, although this perspective with high amplifications becomes extremely abnormal—to some extent comparable to that which results in ordinary vision by a large object being placed close to the eye. Since, however, the appreciation of solid forms is in no case merely a matter of sensation, but always originates in an act of conception, the peculiarity in the optical image referred to would not prevent the solid object being correctly seen under any amplification—at most it could only cause some difficulty by its uncouth perspective—so long as the visual impressions furnished sufficient salient points for the construction of the retinal image as a solid or three dimensional one. For this, however, to be possible it is plainly essential that the solid object should be *simultaneously visible* within a certain not too small depth; for obviously no indications could be derived of the constituents of space if the Microscope at each adjustment only allowed a single layer of inappreciable depth to be clearly recognized. All optical apparatus for obtaining such indications with binocular vision must remain ineffective if the images themselves give no clear impression of anything that relates to the third dimension.

The over-amplification of the dimension of depth inseparable from the action of optical instruments comes, it will be seen, to be an insuperable obstacle to efficient stereoscopic vision with high powers, because as the consequence of that want of proportion in the solid image—and for that reason only—the visual *space* of the Microscope loses more and more in depth as the amplification increases, and approaches more and more to a bare transverse section of the object.

This visual *space*, that is the solid space occupied by the object, which at *one* adjustment of the Microscope is plainly visible to the eye, is made up of two parts, the limits of which as regards the *depth* are determined in a very different manner.

First, the *accommodation* of the eye embraces a certain depth, different planes being successively depicted with perfect sharpness of image on the retina, whilst the eye—accommodating itself consciously or unconsciously—is adjusted by degrees to virtual images of greater and less distance of vision. This depth of accommodation, which of course in the perception of the relations of space plays precisely the same part in microscopical as in ordinary vision, is completely determined by the extent of accommodation of the particular eye, the limits being the greatest and shortest distance of distinct vision. Its exact numerical measure is the difference between the *reciprocal* values of these two extreme distances. If the capacity of accommodation of a particular eye is expressed thus numerically, the depth of accommodation for the same eye in microscopical vision for any given linear amplification may be exactly computed independently of the composition of the Microscope, provided the index of refraction is given of the medium in which the object under observation is placed. The depth of perfectly distinct vision is directly proportional to the above-mentioned numerical equivalent of the extent of accommodation of the eye, directly proportional to the refractive index of the medium of the object, and inversely proportional to the *square* of the amplification when referred always to the same image-distance (say 250 mm.). Assume, for example, that for a moderately short-sighted eye the nearest point of distinct vision is 150 mm., and the farthest point 300 mm.—in which case the numerical equivalent of the extent of accommodation would equal $\frac{1}{300}$ mm.—the calculation for an object in air would give a depth of vision by *accommodation* amounting to

2·08	mm.	with	10	times amplification.
0·23	„	„	30	„
0·02	„	„	100	„
0·0023	„	„	300	„
0·00021	„	„	1000	„
0·00002	„	„	3000	„

all the amplifications being referred to the conventional distance of 250 mm.

These figures would be uniformly increased in the ratio of 3 : 4 or 2 : 3 if the object is supposed to be in water or in balsam. For a more short-sighted eye, but capable of great accommodation, the limits of vision being 200 and 100 mm., the above values for the depth would have to be increased in the ratio of 2 : 3; on the other hand, for a long sight in which distinct vision only reaches to 500 mm. as the nearest point, they must be decreased in the proportion of 5 to 3. The construction of the Microscope (apart from its total amplification) has nothing at all to do with these effects.

Secondly. The perception of depth is assisted by the insensibility of the eye to small defects in the union of the rays in the optic image, consequently small circles of confusion in the vertical image. As a result of this, in a fixed adjustment of the Microscope and a fixed condition of accommodation of the observer's eye, transverse sections of the object which are a little above and below the *exact* adjustment are nevertheless seen without sensible or at any rate prejudicial indistinctness. The total amount of depth so obtained is the so-called *depth of focus* of the Microscope. In order to determine it numerically, the allowable magnitude of the circles of confusion in the microscopical image must be defined by the visual angle under which they may appear to the eye. In accordance with experience, 1 minute of arc would denote the limit for very sharply defined vision, 2 to 3 minutes for vision still pretty distinct, and 5 to 6 minutes the limit for vision only just tolerable. If the amount of the allowable indistinctness is determined in this way, the focal depth depends further only upon the refractive index of the medium in which the object is, the amplification and the angle of aperture of the Microscope (or the angle of the admitted pencil if the whole aperture is not filled with rays), but is quite independent of all other circumstances. Its value may be computed for each particular case from a simple formula, according to which it is directly proportional to the refractive index of the object medium and inversely proportional to the "numerical aperture" of the objective, as also to the first power of the amplification. To take an example; assume the visual angle of allowable indistinctness to be fixed at 5′, and the aperture-angle of the image-forming pencils to be 60° in air (corresponding to a numerical aperture of 0·50), the depth of focus of an object in *air* will then equal

0·073	mm.	for	10	times amplification.
0·024	„	„	30	„
0·0073	„	„	100	„
0·0024	„	„	300	„
0·00073	„	„	1000	„
0·00024	„	„	3000	„

where again the amplification is referred to the conventional image-distance of 250 mm.

By limiting more the amount of allowable indistinctness, all these figures would be correspondingly reduced, and by enlarging the limit they would be increased. On the other hand, they rise in proportion to the refractive index if the objects are in water, balsam, &c. In the same way they would be increased if aperture-angles of less numerical equivalent than 0·50 were made use of, as would always be the case with low powers, and with higher powers if the illumination was by narrow cones of rays, and the objects produced no perceptible dissipation of the incident rays.

It is obvious that the actual *depth of vision* must always be the exact sum of the *accommodation depth* and *focal depth*. The former denotes that object space which the eye, through the play of accommodation, is able to penetrate with perfect sharpness of image; the latter gives the amount by which this object space is extended in its limits—reckoning both from above and below—because without perfect sharpness of image there still remains a *sufficient* distinctness of vision.

The very unequal course of the two constituent parts of the visual depth appears directly from the two series of numbers given above, but will be still more evident if we compare the depth values of both series, calculated for the particular amplifications, with the *lateral* diameter of the field for the same amplifications. The latter—the linear *field of vision* of the Microscope—depends exclusively upon the amplification and upon the angle of field * of the eye-piece employed; and when the latter is taken as constant, is inversely proportional to the amplification, whatever the construction of the Microscope may be. If, for example, the diaphragm of the eye-piece appears under a visual angle of 53° (corresponding to the trigonometrical tangent 0·50 for the semi-angle), then the absolute diameter of the visible field will be

25	mm.	for	10	times amplification.
8·3	„	„	30	„
2·5	„	„	100	„
0·83	„	„	300	„
0·25	„	„	1000	„
0·083	„	„	3000	„

The *accommodation depth* (the same assumptions being made as in the above example) will not remain a constant fraction of the field of vision as would be the case if there were no over-amplification in depth,† but would amount to—

* The "angle of field" of an eye-piece is that angle under which the rays emerge which meet opposite points of the diaphragm. It is at the same time the visual angle under which the field is seen projected by the eye.

† If the amplification of the object were increased 10 times, the absolute diameter of the field would be reduced to $\frac{1}{10}$, and a similar reduction in the depth would leave the ratio of depth to field unchanged.

With	10	times amplification	$\frac{1}{12}$	of the field of vision.
,,	30	,,	$\frac{1}{36}$	,,
,,	100	,,	$\frac{1}{120}$	,,
,,	300	,,	$\frac{1}{360}$	,,
,,	1000	,,	$\frac{1}{1200}$	,,
,,	3000	,,	$\frac{1}{3600}$	,,

The over-amplification of the depth-dimension, inherent in the optical formation of the image, produces therefore, as the amplification increases, a more and more unfavourable relation between the depth and width of the object-space accessible to accommodation. Whilst with 10 times amplification the relation is about that of a pretty thick book, with 3000 times amplification it equals only a single leaf of the book.

The other constituent of the depth of vision, the *depth of focus*, on the other hand, shows an essentially different relation, because the effect of over-amplification is here directly compensated by the narrowing—proportionally to the amplification of the Microscope—of the pencils passing from the eye-piece to the eye. For the limits of perfectly distinct vision by varying accommodation, it is obviously a matter of indifference whether the pupil receives narrow or wide pencils. But the increase in the circles of confusion when the near or distant points of distinct vision are overstepped is proportional to the diameter of the image-forming pencil at its entrance into the eye. The result of this is, that in spite of the over-amplification of the depth-dimension, the solid space recognizable by virtue of the focal depth maintains a *constant* relation between breadth and thickness as long as the same angle of aperture and the same object medium are considered, and as long as a fixed limit is retained for the allowable circles of confusion.

For an effective aperture of 0·50, air as medium, and 5′ as the allowable visual angle of the circles of confusion, this constant relation of depth to the diameter of the field of view corresponding to the depth of focus is $\frac{1}{343}$, consequently a very small fraction, notwithstanding that a pretty wide latitude is here allowed for indistinctness.

The depth is increased to about $\frac{1}{200}$ when under the same assumptions in other respects the object is supposed to be in balsam, and it may be further raised in a considerable proportion when the much smaller angles of aperture are taken into account which are available with lower amplification or with illumination by narrow pencils. These examples show this much however, that when the amplification is low the focal depth in every case falls very much into the background as compared with the accommodation depth, which even for eyes with small capacity of accommodation must still retain a considerable magnitude, whilst inversely under very high amplifications the efficacy of accommodation falls more and more behind the small but constant effect of focal depth.

Combining the preceding figures we have the following table showing the total depth of vision from 10 to 3000 times.

Amplification.	Diameter of Field.	Accommodation Depth.	Focal Depth.	Depth of Vision (Accommodation Depth + Focal Depth).	Ratio of Depth of Vision to Diameter of Field.
	mm.	mm.	mm.	mm.	
10	25·0	2·08	0·073	2·153	$\frac{1}{11 \cdot 6}$
30	8·3	0·23	0·024	0·254	$\frac{1}{32 \cdot 7}$
100	2·5	0·02	0·0073	0·0273	$\frac{1}{91 \cdot 6}$
300	0·83	0·0023	0·0024	0·0047	$\frac{1}{176 \cdot 6}$
1000	0·25	0·00021	0·00073	0·00094	$\frac{1}{266}$
3000	0·083	0·00002	0·00024	0·00026	$\frac{1}{319}$

The result of this discussion shows that direct vision of solid objects in the Microscope depends, with small amplifications, to a preponderating extent on the capacity of accommodation of the eye. The efficacy of *this* factor in small amplifications renders possible to a considerable degree the appreciation of depth, which is the essential postulate of effective stereoscopic effect in binocular vision. That which is contributed by focal depth is under these circumstances inconsiderable. With medium amplifications from 100 up to 200, the effect of accommodation no longer exceeds so greatly the focal depth, and the total perspective of depth resulting from both factors is reduced to a somewhat small fraction of the diameter of the field of view. Its absolute amount still, however, reaches (even with such amplifications) to hundredths of a millimetre with objects that are in highly refracting media and with the use of small aperture-angles. With high amplifications the efficacy of accommodation ceases almost entirely, and the whole visual depth becomes more and more merely focal depth. If the amplification reaches or exceeds 1000, the absolute depth of the visual space is reduced to micromillimetres, and finally to a fraction of μ. The microscopical images of solid objects pass, in this case, more and more into pure *transverse sections.*

The decrease of the visual space and corresponding thereto of the depth of all objects capable of being conceived as *plastic* in binocular vision, proceeds, with the smallest amplifications, approximately as the square of the amplification, and therefore at first very rapidly because with low powers the effect of accommodation is what affects it almost exclusively. With high amplifications, on the contrary, in which focal depth only and no accommodation depth of any consequence exists, the flattening of the visual space proceeds slower, and at last progresses as the first power only of the amplification.

The limited operation of stereoscopic apparatus for other than quite moderate amplifications is therefore apparent. At the same time we are able to gather some hints with respect to the conditions which set limits to the depth-perspective in microscopic vision—on the influence of the medium in which the object is, on the influence of the aperture-angle of the objective, or of the incident illuminating pencils, and on the influence which the very unequal extent of accommodation of the eyes of different individuals must have on the capacity for stereoscopic vision especially with low powers—in particular it leads to a rule of *general* application which should always be applied where stereoscopic observation is concerned, which is—use always the *lowest* amplification sufficient for distinctly recognizing the object, and in observations with transmitted light employ as narrow a pencil as is compatible with sufficient illumination of the image.

In conclusion, we may refer to the general importance in microscopical investigations which this disproportion of amplification in the three-dimensional image of all optical instruments possesses. The foregoing considerations point to the over-amplification of depth-dimension as an obstacle for a more extended application of stereoscopic observation. It should, however, be pointed out that whilst this peculiarity hinders and limits the *direct* appreciation of solid forms, yet it to the same degree supports and extends the *indirect* recognition of space relations. When with increase of amplification the depth-perspective of the Microscope becomes more and more flattened, at the same time the images of different planes stand out from each other in an equal degree more perfectly, and are in the same degree clearer and more distinct. With an increase of amplification the Microscope acquires more and more the property of an *optical microtome*, which presents to the observer's eye sections of the object of a fineness and sharpness that no instrument could produce by mechanical means. The over-amplification of the depth is the foundation of this capacity in the Microscope, which enables the observer by successive adjustments for a series of consecutive planes to *construe* the solid forms of the smallest natural objects with the same certainty as he is accustomed to *see* with the naked eye the solid forms of macroscopic objects. It cannot be doubted that this positive gain from the peculiar action of optical systems is a far greater advantage in the general scientific use of the instrument than could ever be expected from an extended application of stereoscopic observation.

☞ Since the original publication of the above paper, Professor Abbe has sent us the following brief summary of the principal formulæ which are the basis of the preceding discussions.

(1) The *over-amplification of the depth* in the solid microscopical image results from a general proposition, which may be expressed in the following way. Let A and B denote two points on the axis of an optical system on the side of the object, and δ their distance; M the linear amplification of a plane object at A, N the linear amplification of a similar object at B, and δ^* the axial distance of the two images on the other side of the system; n and n^* the refractive indices of the media in front and at the back: then we have always

$$\frac{\delta^*}{\delta} = \frac{n^*}{n} \text{ M N}$$

whatever may be the composition and focal length of the system, and in whatever position A and B and their images may be supposed.

The quotient on the left-hand side of this equation expresses the *axial* amplification of a solid object extending from A to B, and shows this axial amplification (or the amplification of the *depth*) to be proportionate to the *product* of the *lateral* amplifications of the extreme layers of the object (or to the *square* of the geometrical mean of those amplifications).

If A and B are situated on the same side of the principal focus of the system (both in front and both behind), and their distance δ is taken shorter and shorter, the value of M must approach more and more to N, and the formula will give

$$\frac{\delta^*}{\delta} = \frac{n^*}{n} N^2,$$

and

$$\frac{\delta^*}{\delta} = \frac{1}{n} N^2,$$

if the medium at the back of the system is air ($n^* = 1$), as is the case with the Microscope.

Though the above general proposition has not yet been recorded, the fact that the axial amplification increases for short distances with the square of the lateral amplification has been noticed by various writers. The influence of this marked feature of optical delineation on the performance of optical instruments has not, however, been previously pointed out.

(2) The *depth of accommodation* (a) in microscopical vision depends on the range of accommodation of the observer's eye in direct vision. If S denotes the longest and s the shortest distance of distinct vision for a given eye, the range of accommodation is strictly defined by the expression

$$\frac{1}{s} - \frac{1}{S} = \lambda.$$

If, now, the equivalent focal length of an optical system is $= f$, and the object is in a medium of refractive index n, the absolute depth of the object which is embraced by the accommodation is

$$a = n f^2 \lambda.$$

If N is the linear amplification of a virtual image projected by the system at a distance L from its posterior principal focus (which in the case of the Microscope is the "eye-point" above the eye-piece), we have

$$f = \frac{L}{N},$$

and therefore

$$a = n \left(\frac{L}{N}\right)^2 \lambda.$$

(3) In order to determine the *depth of focus* (ϕ) of a system which projects virtual images to an observer's eye, we must first define the degree of indistinctness which is allowed for these images. This may be done in the simplest way by indicating the visual angle under which the *admissible* circles of indistinctness (or dissipation-circles arising from the deviation of focus) appear in the virtual image. If ω denotes this angle of allowable indistinctness (and is expressed by its *arc* $- 1' = \frac{1}{3438} = 0 \cdot 000291$), f the equivalent focal length of the total Microscope, or whatever other system may be in question, a the *effective* numerical aperture, and n the refractive index of the medium in which the object is, the *depth of focus* is determined by the equation

$$\phi = n \frac{f}{a} \omega$$
$$= n \frac{L}{N} \frac{\omega}{a}.$$

If the whole aperture-angle of a system is utilized by the delineating pencils (as is generally the case with low apertures), a relates to the whole *aperture.* If, however, a narrower illuminating pencil is used, and not subjected to a considerable dissipation by the structure of the object, a relates to the angle of the *admitted pencil* only.

The actual *depth of vision* is *depth of accommodation* (α) + *depth of focus* (ϕ). We have therefore

$$\textit{Depth of vision} = n \frac{L^2}{N^2} \lambda + n \frac{L}{N} \frac{\omega}{a}.$$

The figures resulting from this formula are obviously not affected by the arbitrary value of the distance (L) of projection to which the figures of the amplification (N) may relate, because with one and the same system N is always proportional to L.

(4) The absolute *diameter of the field* which is visible in the Microscope depends on no other element but (a) on the equivalent focal length of the total system, and (b) on the *angle* of field of the *eye-piece*, which is the visual angle under which the clear diaphragm-hole of the eye-piece appears to the observer's eye. Let u denote the *semi*-angle of field, f the focal length, or N the total amplification of the Microscope for a certain distance L of the image, the linear diameter of the visible object-field is determined by the equation

$$d = 2 f \tan u = 2 \frac{L}{N} \tan u.$$

These are the dioptrical formulæ on the basis of which the examples of the foregoing discussion have been calculated.

Abbe's Stereoscopic Eye-piece.—We should have mentioned, in describing this at p. 298, 1st, that a special feature of the apparatus is its capability of being used with the highest powers; and 2nd, that it is not necessary to cover up half of *each* of the eye-piece tubes, thus losing half the total amount of light. It is sufficient if *one* only (the lateral one) is half obscured, leaving the other free. As the normal division of light between the two tubes is two-thirds (in the axial) and one-third (in the lateral), the total loss of light is reduced to one-sixth.

The field of view of the axial eye-piece in this arrangement in any case necessarily appears brighter than that of the lateral one seen with the same eye; and in regard to this, Professor Abbe remarks * that the difference between the brightness of the two fields in binocular observation "is not only no defect, but on the contrary a decided advantage. For experience has long proved that to obtain a good stereoscopic effect it is only necessary that *one* image should be as perfect and clear as possible, whilst the other may, without appreciable disadvantage, be of sensibly less perfection.† It might therefore be anticipated that this would apply (as in fact it does) in the same way to difference of luminosity. Moreover, an additional fact must be taken into account—that the two eyes, especially of microscopists, always show unequal sensibility to light as the result of constant unequal use. The less used eye, whose acuteness of vision is always less than that of the one more frequently exercised, shows a greater sensibility to light, and the difference is so considerable that the less luminous image of the lateral eye-piece, when viewed with the less exercised (generally the left) eye, seems even brighter than the other when viewed with the exercised eye. The unequal division of the light is therefore a welcome element, as it serves to equalize this physiological difference. The observer has only to take care that the less used eye is applied to the lateral eye-piece."

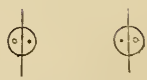
Illumination for Binocular Microscopes with High Powers.‡—Referring to the plan explained in the preceding note for half covering up only one of the eye-pieces, Professor Abbe says:—"On the other hand, there are cases—especially when high powers are used for binocular observation—where the simultaneous covering up of both eye-pieces may be of good service, whilst at the same time the loss of light may be fully compensated by the method of illumination. All stereoscopic vision with the Microscope, as far as it is anything more than mere *seeing with two eyes*, depends exclusively upon the unequal inclination of the pencils which form the two images, to the plane of the preparation or the axis of the Microscope. By uniform halving of the pencils, whether by prisms above the objective or by diaphragms over the eye-pieces, the difference in the directions of the illumination in regard to the preparation reaches approximately the half of the angle of aperture of the objective, provided that its whole aperture is filled with rays. By the one-sided halving we have been considering, the direct image is produced by a pencil the axis of which is perpendicular to the plane of the preparation, and the deflected image by one whose axis is inclined about a fourth of the angle

* Zeitschr. f. Mikr., ii. (1880) p. 207.
† Cf. Carpenter, 'The Microscope, &c.,' 6th ed. (1881) p. 36.
‡ Zeitschr. f. Mikr., ii. (1880) p. 207.

of aperture. With low powers, which allow of a relatively considerable depth-perspective, the slight difference of inclination, which remains in the latter case, is quite sufficient to produce a very marked difference in the perspective of the successive layers in the images. But with high powers the difference in the two images does not keep pace, even when both eye-pieces are half covered, with the increase of the angle of aperture, so long as ordinary central illumination is used. For in this case the incident pencil does not fill the whole of the opening of the objective, but only a relatively small central part, which as a rule does not embrace more than about 40° of angle, and in most cases cannot embrace more without the clearness of the microscopic image being affected, and the focal depth also being unnecessarily decreased. But as those parts of the preparation which especially allow of solid conception are always formed by direct transmitted rays in observation with transmitted light, it follows that under these circumstances the difference of the two images is founded, not on the whole aperture-angle of the objective, but on the much smaller angle of the incident and directly transmitted pencils, which only allow of relatively small differences of inclination of the image-forming rays to the preparation. It is evident, however, that when objectives of short focus and correspondingly large angle are used, a considerably greater differentiation of the two images with respect to parallax can be produced, if, in place of *one* axial illuminating pencil, *two* pencils are used oppositely inclined to the axis, in such a way that each of the images is produced by one of the pencils. This kind of double illumination, though it cannot be obtained by the simple mirror, can be easily produced by using with the condenser a diaphragm with *two* openings (Fig. 160), placed in the diaphragm stage (or carrier) under the condenser. We then have it in our power to use at pleasure pencils of narrower or wider aperture and of greater or less inclination towards the axis, by making the openings of different width and different distance apart. With diaphragms of this form (which can easily be made out of card), the larger aperture angles of high-power objectives may be made use of to intensify the stereoscopic effect without employing wide pencils, which are prejudicial, both as diminishing the clearness of the image and the focal depth. Of course, with this method of illumination *both* eye-pieces * must be half covered, in order that one image may receive light only from one of the two illuminating cones, and the other only from the other. The division of light in both the aperture-images will then be as shown in Fig. 161, and it is evident that in this case the brightness of the image for both eyes together is exactly the same as would be given by one of the two cones alone without any covering.

Fig. 160.

Fig. 161.



* That is, of the Abbe Stereoscopic Eye-piece.

The method of illumination here referred to—which was originally recommended by Mr. Stephenson for his binocular Microscope—has in fact proved itself to be by far the best when it is a question of using higher powers than about 300 times. It necessarily requires very well corrected and properly adjusted objectives if the sharpness of the image is not to suffer; but if these conditions are satisfied, it yields most striking stereoscopic effects even with objectives of 2 mm. and less focal length, provided the preparation under observation presents within a small depth a sufficiently characteristic structure."

We need hardly point out to microscopists the practical importance of the suggestion for on the one hand retaining the *advantage* of wide apertures to utilize the effects arising from *parallax*, while on the other hand neutralizing the *disadvantage* of such apertures in the loss of *focal depth.*

"Working Distance and its relations to Focal Length and Aperture." *—Mr. E. Gundlach has an article on this subject, which we regret not to be able altogether to follow, but we give his definitions and conclusions:—

"Working distance is the usual designation of the space between the object and the objective on a Microscope when the former is brought into proper focus; or, in other words, when the objective is brought to such a distance from the object that by means of the former an air-image of the latter may be formed at a distance of 10 inches.

"The working distance of an objective depends upon (1) the focal distance, (2) the aperture, (3) the number of lenses of which the objective consists, (4) the proportionate curvatures of the lenses, (5) the thickness of the lenses. . . . .

"The working distance of an objective may be expressed numerically, from a comparison of the theoretically longest working distance as unity, and the result may be called the 'numerical working distance.'

"As a single lens without thickness cannot be produced, the actual working distance of an objective will be much less than the unit of the numerical working distance. . . . .

"If f is the focal length, a one-half of the angle of aperture, d the *actual* working distance, n the *numerical* working distance of an objective, then

$$n = \frac{d}{f} \div \cos a.$$

* * * *

"(1) If two objectives have equal focal length and equal working distance but different angles of aperture, then the one with the larger angle of aperture has the greatest numerical working distance.

"(2) If two objectives have equal focal length and equal numerical working distance but different angles of aperture, then the one of the larger aperture has the shortest actual working distance. . . . .

"(4) The actual working distance of an objective is in direct proportion to the numerical working distance."

* Amer. Mon. Micr. Journ., ii. (1881) pp. 32–3 (2 figs.).

Invention of the Binocular Microscope.—Some controversy has recently taken place in America * on this subject, having been opened by a paper from Colonel J. J. Woodward, in which he complained that the claim of Dr. J. L. Riddell, Professor of Chemistry in the University of Louisiana, to be the inventor of the binocular Microscope had not been properly recognized in England.

It appeared, however, that Colonel Woodward in writing his paper had, by some strange accident, overlooked the fact † that both Mr. Stephenson and Mr. Wenham had publicly acknowledged Professor Riddell's priority,‡ and it may be added that the original papers of the latter were duly published in this country at the time.§

Colonel Woodward also objects to Dr. Carpenter having given to MM. Nachet credit which really belongs to Professor Riddell in regard to the form of binocular Microscope introduced by that firm, as to which, however, Mr. Wenham points out that M. Nachet's modification was a notable improvement and real advance upon Riddell's original idea.

We do not believe that any one in this country would venture to dispute the right of Professor Riddell to the title of "Father" of the binocular Microscope. Certainly, as the references given in the previous foot-note show, those who have subsequently so successfully improved upon Riddell's original ideas have never attempted to do so.

At the same time it is only fair to recall the fact that if the binocular Microscope had not advanced beyond the point at which Riddell left it, the use of the instrument would be very limited, and where now there are 100 binoculars to be found there would not then have been one.

Priority of Invention.—There is getting to be more and more of a tendency in modern times for authors or inventors who have at some period or other dealt with a given subject, to attempt to claim for themselves the credit of any modifications or improvements which may have been subsequently made by others, even although those improvements may for the first time convert an impracticable idea into a workable one. This has even been carried to such a point that suggestions which the authors themselves originally condemned and discarded as useless in practice have been again claimed, when it was subsequently shown (from another point of view) that they could be made available.

The question of oil immersion itself is a leading example of this, for although the use of oil was suggested at the same time as water, it was discarded in practice as not presenting any advantages, wholly and entirely through want of the knowledge that the apertures of oil or water immersion objectives exceed the maximum of dry

* Amer. M. Micr. Journ., i. (1880) pp. 221–30 (2 figs.); ii. (1881) p. 29. Amer. Journ. Micr., vi. (1881) pp. 14–15.

† Amer. M. Micr. Journ., ii. (1881) pp. 29–30 (Mr. Stephenson's reply). Amer. Journ. Micr., v. (1881) pp. 26–7 (Mr. Wenham's reply).

‡ Mon. Micr. Journ., x. (1873) p. 41.

§ See Quart. Journ. Micr. Sci., i. (1853) pp. 236, 304; ii. (1854) p. 18.

objectives in the same ratio as the refractive indices of the immersion fluids (1·52 or 1·33) exceed that of air (1·0). In the absence of that knowledge, the benefit of oil over water necessarily seemed to be very small—too small in fact to compensate for its disadvantages in use. The appreciation, however, of the increase in aperture—in the delineating power of the Microscope—at once changed the whole position and led to homogeneous immersion.

In fact, to no class do the following words of A. De Morgan* more aptly apply than to microscopists (italics as in original):—

"I have never found notice of any case of the theorem in any writer prior to Cavalieri. For this occasion I have cursorily examined the likely places of Maurolycus, Fernat, Sterinus, and Des Cartes, without finding anything which offered a chance if the search were pursued. But if, which is possible, any anticipation of a case or two should be discovered or even the theorem itself, unapplied, I should not the less give it the name of Cavalieri. I have come to a settled conclusion that *great points belong to those who made great points of them.* The history of mathematical discovery is vexed with never-ending disturbances arising out of claims of priority, which mean that this person threw the thing away before that person used it. In many cases it is by no means certain that this person ever saw in his own words or formulæ what that person enables *us* to see. Giving due moral blame to any one who consciously suppresses a hint which he knows he has taken, I consider that an inventor who is the first user has a position from which a hundred previous inventors cannot dislodge him, nor do anything but enhance his merit as the *inventor of the use*, most often the more difficult invention of the two."

β. Collecting, Mounting, and Examining Objects, &c.

Colouring Living Infusoria, &c.†—M. A. Certes gives further details as to the solution of cyanine which he makes use of for colouring living infusoria.‡

He finds that with a solution of 1 : 500,000 the colouring power of the cyanine is still sufficient. Although stronger doses have been used, they have never exceeded 1 : 100,000. As distilled water is poisonous to infusoria, aqueous solutions of cyanine must be prepared with ordinary filtered water. Whether the solutions are aqueous or alcoholic, all decolorize more or less rapidly in the light, so that they require to be kept in the dark.

Unmixed Cultivation of different Bacteria.§—K. J. Salomonsen has adopted the following mode of obtaining unmixed cultures of different putrefaction-bacteria. An absolutely pure sowing was taken from putrefaction-specks in defibrinized ox-blood, which had been preserved and observed in capillary tubes. In order to obtain as large a number as possible of different forms, he chose (1) those

* Trans. Camb. Phil. Soc., xi. (1866) p. 200.
† Zool. Anzeig., iv. (1881) pp. 287–8.
‡ See *ante*, p. 527.
§ Bot. Ztg., xxxviii. (1880) pp. 481–9.

specks which presented the greatest possible differences in reference to time of incubation, rapidity of growth, and appearance; (2) specks from the blood of different individuals; and (3) he employed that blood only which contained a small number of specks, which were, therefore, at a distance apart. The piece of the capillary tube, the contents of which were going to be sown, was then separated under water by a strong pair of scissors, and placed in the culture-bulb, with the requisite precautions—viz. using all the instruments immediately after strong heating, to destroy the dust, &c. A bulb was used for this purpose provided with a rather short (4 cm.) and relatively wide neck, with only a small opening, closed by a wad. The wad was composed of a caoutchouc tube, which was so firmly closed for half its length by a small wad-stopper that it was slightly bulged. The tube was somewhat wider than the upper end of the neck of the bulb, that it might be placed on it without difficulty, but narrower than the lower part. After the requisite quantity of the nutrient fluid had been drawn into the bulb, and the latter closed, the definite purification and sterilizing were effected by boiling.

The author gives a tabular description of forty specks, and of the bacterial forms obtained from them, with information as to the period of incubation, rapidity of dissemination, &c. Six bulbs showed no development of bacteria. The remaining thirty-four contained at least seven different Schizomycetes—viz. four morphologically different bacilli in four bulbs, characteristic Streptococci in great chains and knots in four, and in twenty-six cocci which were easily divided into micrococci and mesococci. But the latter must also, in any case, include a variety of species, since a microscopic examination of each of the two groups revealed very considerable morphological differences. In some of the bulbs was nothing but diplococci, in others cocci of equal or unequal sizes, while in others they were of a comparatively gigantic size. A macroscopic examination also brought out great differences. With the motile bacilli there was always a diffused turbidity of the fluid, while the motionless cocci appeared as greyish or whitish specks, which formed peculiar figures on the walls; or they accumulated in masses at the bottom, or covered the wall as a connected easily destroyed pellicle.

These appearances recurred when the organisms in question were transferred to other bulbs with the same nutrient fluid. With reference to the rapidity of dissemination in the nutrient fluid (infusion of flesh), the micrococci were distinguished by their sluggishness.

False Appearances produced by Hardening.—Dr. G. H. Savage, of Bethlem Hospital, writes:—

"It is of the utmost importance that, in drawing conclusions from hardened specimens we should know what changes may be produced by the reagents used for preserving. As I am in some doubt as to the changes produced by spirit on nervous tissues, I write to ask the aid of brother microscopists as to the changes they have found in spirit-hardened specimens. I am more especially interested in the changes produced in nervous tissues by spirit, and I should be glad to hear from others their experience on the matter, not alone in human tissues but in those of the lower animals.

My present belief is, that if nervous tissues are placed at once in spirit they will sooner or later show the presence of bodies which do not stain with carmine or logwood, and which, in some cases, do stain with osmic acid. These bodies are not all alike; some have a very suspicious foreign appearance, but others are so like some degenerations that they have been described as such. Some are of irregular rounded outline of varying size; some do take staining in a faint way, and some have a semi-crystalline look which confirms one's idea that they are not antemortem, but the result of the process of preparation. What I should specially like to know is if others have met them in similar conditions. Spitka of America described such bodies, and I have heard—but have not the references—that certain German writers recognize them as artificial.

In describing my experiences, I would say that they appear in nervous tissues when these have been in spirit for not less than two months, and that they are more common in the white matter, at all events at first; the more crystalline bodies, in my experience, do not occur till later. I believe that some of the non-staining bodies are due to a breaking up of the white matter of Schwann. Again, I believe that if the specimens are placed in spirit without being finely divided before hardening, they are more liable to produce these bodies. I shall be happy to provide any one with specimens if they will further investigate the matter."

Hailes' Poly-microtome.—Dr. Hailes sends us the following directions for using this instrument, which was described at p. 1036 of vol. iii.:—

When the microtome is used for freezing, remove the glass table, and cover the ice-jacket with felt or gutta-percha, to prevent absorption of heat from the atmosphere. Oil the screw and plunger, to prevent them becoming fixed by the freezing (too much oil interferes with freezing); screw the cylinder into position on the bed-plate. Enclose the top with a tightly fitting cork, to prevent the entrance of ice, &c. Put on the hopper cover, and fill the ice-jacket with very finely powdered ice and coarse salt, through the hopper, and stir the contents by rotating the hopper cover. In a few moments the cylinder will be cooled down to freezing-point. Remove the hopper lid, and cork and fill the cylinder two-thirds full with mucilage acacia, British pharm.; then replace the cork and hopper lid, and stir for a few moments.

When a white frozen film has formed at the periphery, then introduce the previously prepared specimen into the mucilage in the well of the microtome, holding it against the advancing film of ice until it becomes fixed in the desired position; then pour in a little more mucilage so as to cover it completely, recork the cylinder and replace the hopper lid, and stir, adding ice and salt as it becomes necessary, until the specimen is solidly frozen.

When perfectly frozen, exchange the hopper lid for the glass table, which has previously been cooled by contact with ice, then cut in the usual way, an assistant working the lever alternately with the cutting. The thickness of the cutting is controlled by the regulator, as shown on the index ; the thickness most generally employed is $\frac{1}{1200}$ of an inch. (These measurements are approximal.) The temperature at which the best results have been attained has been where the surrounding atmosphere was about 40° Fahr. If during cutting the tissue becomes softened, it must be refrozen ; this is accomplished by disengaging both pawls, and causing the plunger to descend rapidly by turning the micrometer screw direct by the knob on the ratchet-wheel. The cylinders being interchangeable, the tin cylinders are slipped over the brass ones previous to interchanging them ; thus no delay takes place. Two hundred sections have been successfully cut in a single minute, but a more moderate rate of about 100 per minute is recommended.

Figs. 162 and 163, one-fourth original size, show the instrument arranged for freezing with ether spray, rhigoline, &c. In Fig. 162,

Fig. 162.

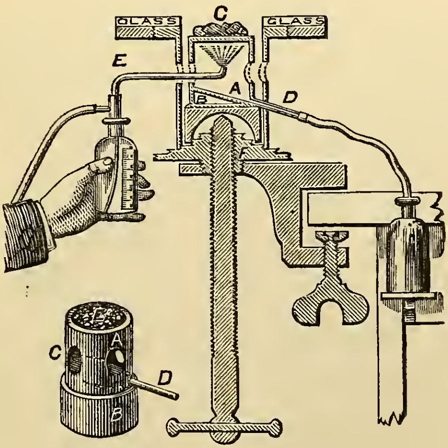


Fig. 163.

A is the zinc cylinder or spray chamber ; B, false or sloping bottom for conducting condensed ether ; D, exit tube leading to collecting bottle ; C, object to be frozen ; E, ether spray apparatus ; F, pyramidal bed-plate, &c. In Fig. 163, A is the zinc cylinder ; B, plunger of microtome ; C, opening for spray instrument, &c. ; D, exit tube for collecting condensed ether ; E, roughened top, to facilitate the retention of the frozen object in position.

Williams's Freezing Microtome.—This (Fig. 164), the design of Mr. J. Williams, and made by Messrs. Swift, consists of a wooden "tub" pitched inside (holding about 2 pints) to receive the freezing mixture, having in the centre a brass standard, into which screw the brass circular plates on which the material to be frozen is put. One of these plates is shown in place with three others in front, the hollow one for hard and other substances which require fixing in some kind of cement, &c., and the oblong one for preparations of larger size. The vessel is closed by a top with a glass surface, having a central hole through which the circular plates project slightly. The knife—the edge of which only comes into contact with the substance cut—is fixed into a triangular frame, which moves freely on the glass surface. By the three screws at the angles the frame, and with it the knife, can be raised or lowered for adjustment in any desired plane. The other two screws attached to the frame are for supporting the knife, which has two notches fitting into grooves near the points of the screws. A third horizontal screw presses the knife against the first two screws and keeps it tightly in place. The screw seen at the left-

Fig. 164.

hand side of the ice vessel is for the purpose of clamping the top, and the indiarubber tube carries away the drainings as the ice melts. It is claimed that this instrument will keep the preparation in a frozen state for hours after once charging with ice and salt, and readily cuts sections $\frac{1}{1000}$ inch thick.

The method of using the microtome is as follows:—

Remove the cover and fill the chamber with equal parts of pulverized ice and salt, care being taken not to allow the mixture to touch the under side of the cover, which, when replaced, must be firmly secured by the clamp screw for that purpose. The substance to be cut must be placed on the surface of one of the circular plates, and surrounded with a little common gum-water, which readily congeals and thus holds the specimen firmly in position, which will solidify shortly after the gum has frozen. The edge of the razor must be elevated to the required height for cutting the section by means of the three screws supporting the frame. After the first cut, each end of the razor must be again presented to the surface of the specimen, when either end of the blade can be adjusted by one of the centre screws until its entire length is level, then by turning the larger screw at the apex of the frame it can be lowered for each successive section required. One entire revolution produces a section $\frac{1}{100}$ of an inch in thickness.

The screw-head being divided into sixths, one division gives a section of $\frac{1}{600}$ of an inch, and thinner ones can be produced by proportionately turning the screw. Substances that have been previously prepared in spirit or chromic acid require to be steeped in syrup for twenty-four hours beforehand, otherwise they will not readily congeal. It is advisable to cover the apparatus with baize to facilitate the operation of freezing. When it becomes necessary to sharpen the razor, it can easily be removed for that purpose, but when replacing it, care must be taken to arrange it parallel and with the edge a trifle lower than the back, so as not to deface the preparation. Too much force must not be exerted in clamping the razor in position, as the blade is liable to twist or bend.

Zeiss's Microtome.*—Dr. Körting describes this instrument, the first incentive to the construction of which originated with Professor Lichtheim as a desirable improvement on the Leiser form.

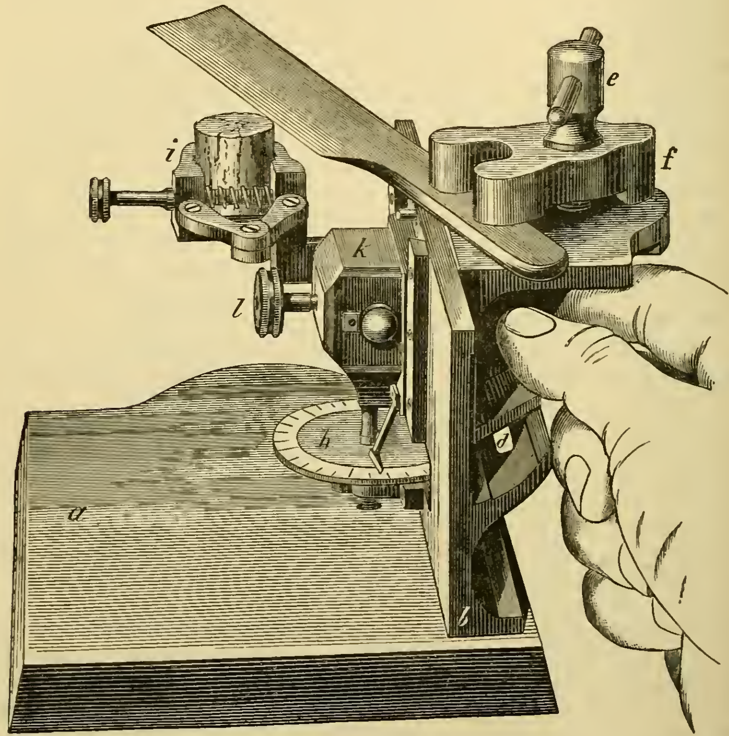
The microtome (Fig. 165) consists of a broad cast-iron foot *a*, to which a brass upright *b* is screwed. To this is fixed, on the right, a piece *d*, which is planed smooth, and allows the knife-carrier (14 cm. long) to slide along it. To prevent it slipping off, there is a groove, in which moves a button attached to the under side of the knife-carrier. The knife is fixed by the screw *e*, which clamps the handle between two brass plates, the surfaces of which are plane and smooth. When the upper plate *f* is turned round *e* towards the left, the knife can easily be taken out and put in. The knife itself is so shaped that it can be held in the hand and used to make free-hand sections if wanted. It most resembles the knife of Fritsch. The blade can be fixed at angles between 62° and 24° to the sagittal axis of the object. As the latter angle, especially when the object is very delicate, does not exclude the pressing action of the knife to the extent desired, Dr. Körting prefers for his instrument a knife whose blade forms an obtuse angle of 150° with the handle. This can be placed at such an acute angle with the object that 5 cm. out of the 7 cm. of the knife blade can be drawn through an object 7 mm. in diameter.

To the left side of *b* a movable plate is attached, sliding between two flanges, and to it the object-clamp is fastened. It is elevated by a micrometer screw, a complete turn raising the object-carrier 0·3 mm. The graduated head *h*, divided into 30 degrees, marks hundredths of a millimetre in elevation. The clamp *i* can be turned about a pivot

* Jen. Zeitschr. Naturwiss., xiv. (1880) p. 193.

in the block *k* (fixed to the movable plate), so that the cutting surface of the object in the clamp can be presented more or less obliquely to the blade of the knife. The binding screw *l* fixes it in the various positions. The clamp may be turned down so far as to allow the object to be removed without coming too near the knife. If required, a box is provided as well as the clamp, in which delicate objects may be imbedded.

Fig. 165.



Dr. Körting considers the fixing of the clamp a most essential improvement. When perfectly fixed, it stands off at such a distance that a vessel can be placed underneath so as to catch all the drops that fall, without wetting the other parts of the instrument or the hands, &c. This is very important for those who work in the house.

Preparing Coal Sections.—Professor P. F. Reinsch gives the following directions for preparing sections of coal:*—

A plane cut, as in rock and mineral sections, generally is not serviceable; the cut must be made in relief. Thus only the different

* See transl. in Amer. Natural., xv. (1881) pp. 498–9.

forms can be brought out, as according to their hardness each form will become more or less transparent, since the softest parts will be worn faster, and hence be finally thinner and more transparent than the more resisting forms. Sections parallel to the bedding are made without difficulty; not so sections at right angle. Much precaution is to be exerted with these. Cut the raw plate with a steel saw 4 mm. thick, 15 mm. square. Make a plane cut as usually in rock sections, but using only the finest emery (polishing emery) or precipitated carbonate of calcium. Then rub the surface gently in all directions with a cork plate (perfectly soft and no grains) 10 mm. square, and moistened with a drop of glycerine. This treatment produces the relief. Frequent examinations must be made under the Microscope, to observe the point where the desired transparency has been reached (not less than 0·01 mm.). In some cases, as for trichites and grammites, it is best to warm the raw plate and saturate it with a mixture of wax and paraffin. When attaching the plate to the support, it should neither be heated too long with the balsam nor too short a time, the first excess causing the plate to warp, crack, and inducing a partial alteration of some of the coal constituents; too little boiling causes the plate to detach itself from the support during the process of grinding. Chemical treatment with acids or alkalies is not advisable.

A microscopic image of the condition of things in a coal section may be obtained by closely inspecting a sharp cut through a compressed ball of hay. Here the innumerable plant individuals are cut in every direction. The different sections of the same plant have often so little in common that an identification of the species is extremely difficult. This is true of a microscopic coal section; and only the comparison of very many specimens will establish the common characters of the forms. Professor Reinsch's conclusions, to which we referred at page 836 of vol. iii., are drawn from 1200 perfect sections.

Simple Method of making Rock Sections.*—The process of reducing stone and other hard substances to thin sections for microscopical examination by the methods usually employed by amateurs is, Mr. W. C. Brittan considers, both tedious and laborious, requiring a great amount of patience and some ingenuity, with a commonly unsatisfactory result; and he therefore gives some suggestions from his own experience that are very efficacious with all substances not too hard to be reduced by grinding with emery.

Take a piece of plate glass—3 × 4 inches is a very convenient size—set in a block of wood; a circular piece of inch-thick pine, with three screw-heads placed triangularly underneath, will be found to give it great solidity upon the table, a qualification very desirable in doing delicate work. Upon this piece of glass, with emery and water, grind one side of a glass slip to an evenly ground surface. Next, take the stone or other substance from which a section is to be made, and in the same way grind down one side of it to a suitable face.

* Amer. Journ. Micr., vi. (1881) p. 12.

Place a drop of balsam on the ground surface of the slide, pass it over the flame of the lamp until sufficiently hard to chip when cold; while still hot, place the stone in position, press down as close as possible, being careful not to enclose air-bubbles underneath. It is also important that the object be perfectly dry, as any moisture would cause air-bubbles when placed in the hot balsam. This part of the process should be carefully done; for the object is now on its final resting-place, and is not again to be disturbed. When the slide is cold, with alcohol, or ether, clean away all the surplus balsam, return to the glass slab, and grind down the other side of the section as thin as desired, using the finest grade of emery in finishing. In this way sections of almost any size and uniform thickness can be made perfectly free from breaks and flaws.

After the slide has been thoroughly washed and dried, it is ready for the cover-glass. Place a drop of turpentine upon the object, allowing it to spread entirely over it without excess; this expels the air and prepares it to receive the balsam. Next put a drop of balsam on the cover-glass, and harden over the flame as before, only not quite so hard this time; let it cool a little, turn it over, and place the drop, which hangs suspended, upon the centre of the object; heat the slide again very slowly over the flame until the cover gradually settles to its place, then gently press it home. When cold, clean away all the surplus from around the cover, wash thoroughly with soap and water, and the slide is finished. This process cannot be followed with any other than the ground-glass slip. If the ordinary slip be used, the object must be transferred from the glass upon which it is ground to the slide upon which it is mounted, which, in very delicate sections, is most difficult to do without breaking.

Tin-foil Cells.*—Mr. A. H. Chester commends cells cut out of different thicknesses of tin-foil and finished on a lathe.

The object is first fastened to the slide (centered on the turn-table) by means of a weak solution of gelatin, gum-water, or Brunswick black. For very small objects a small circle of the gelatin is turned in the centre of the slide, and then allowed to dry. The objects are arranged on the spot, and then, by carefully breathing on the slide, they are fixed in position. If larger objects are to be fixed to the slide, a spot of gelatin or gum that the object will entirely cover is put on, and after drying, the object is fixed in the same way. For larger and heavier objects a circle of Brunswick black is turned, and after it has been thoroughly hardened by heat, so that when cool a needle point will not mark it easily, the object is arranged on the spot and fastened by warming again.

In whatever way the object is fastened, the next thing to be done is to lay the slide on the plate and heat it until it is perfectly dried and ready to be covered.

The slide is then centered on the table, and a circle of shellac, which has been thickened and coloured with Chinese vermilion, is run around the specimen, at such a distance from it that its inner

* Amer. Mon. Micr. Journ., i. (1880) pp. 233–4.

edge is just larger than the cell to be used. The cell is then laid on, centered, and pressed hard to set it. If the slide is slightly warm and the cement thick, it will not run at all, but will hold the cell firmly in place, so that the cover can be put on at once. If it is thin, it must first be allowed to harden somewhat. When ready, as it will be in a few moments if properly managed, a ring of the same cement is run on the cell, and the cover is then laid on, pressed down, clipped in position, and the mount laid aside to harden. It is well in an hour or so to remove the clip and run cement in the joints between cover-glass cell and slide, in order to be certain that no air-holes remain. It can then be reclipped, and set aside until the cement is perfectly hard. The mount is complete, and will last a long time if proper care is taken of it. For security it is well to put on additional rings of cement more elastic than the shellac, and to make a final finish for the sake of appearance. A ring of white zinc cement should therefore be put on, which completely fills up the joints, and makes a smooth surface from cover-glass to slide. This must harden several days, and the slide is then complete, unless additional rings are run on for a finish.

In making the rings on slides it is not always easy to make the edges true, and sometimes the cement spreads too far. In such cases they should be turned down with the point of a knife until they suit. If the cement is taken just at the right time this is easily done, and it improves the appearance very much.

Mr. A. Y. Moore also commends * tin-foil cells, which he makes as follows :—

Flood a clean *warm* slide with lacquer (a weak solution of shellac and alcohol), allowing it to drain from one corner. The heat of the slide causes a rapid evaporation of the alcohol, leaving a film of shellac on the slide. Prepare a piece of clean flat tin-foil, a little larger than the outer diameter of the cell required. Heat the slide till the film of shellac is melted, taking care not to boil it. The foil should then be placed upon the centre of the slide, and firmly pressed against it, so that it may adhere at all points. In a few minutes the slide will be cool, and the film firmly adherent. It may now be placed upon the turntable, and with the point of a sharp knife-blade two clean cuts should be turned through the foil, one for the outer and one for the inner edge of the cell. As soon as the cuts are made, the superfluous tin should be scraped away and the slide cleaned with alcohol; it is then ready for use. The cement is hard, and no time need be wasted in waiting for it to dry, as in ordinary cells.

Wax Cells.†—Mr. W. H. Gilburt finds, as the result of using wax for a long time past, that dewing is avoided by building up the cells. He spins up the wax on the slide, using melting wax and a turntable. The cover adheres by itself, and he has not found any condensation of moisture whatever, the heating of the wax seeming to get rid of the volatile element. In finishing off, it is best to use first a thin coating

* Amer. Journ. Micr., vi. (1881) pp. 29–30.
† Journ. Quek. Micr. Club, vi. (1881) pp. 215–6.

of oxide of zinc in gum-water and then put on the finishing coating afterwards.

Wax Cells—Decomposition of Glass.—Herr E. Weissflog of Dresden writes to Professor Hamilton L. Smith * that he considers that wax cells must be thrown aside. He has a number of preparations of diatoms from Eulenstein made with wax cells which are completely spoilt and the covers loose. Herr Lindig of Dresden, who has had much experience in mounting, and has for many years endeavoured to find some reliable cement, has arrived at the result that shellac is the best, and he now uses nothing else.

At the same time, Herr Weissflog is decidedly of opinion that the spoiling of preparations is partly due to the glass. He has slides of the best plate-glass, and when they are packed away the outer surface appears after a time covered with moisture. He has also often found numerous crystals on Chance's cover-glass, which appear to come from a kind of sweating or decomposition of the surface.

Arabin for Mounting.†—Mr. H. J. Waddington says that "arabin," or gum arabic from which all impurities have been removed, will be found valuable to microscopists for attaching diatoms, &c., the ordinary gum arabic presenting a granular appearance.

To obtain arabin for microscopical use clear and white gum arabic should be selected, and dissolved in distilled water to the consistency of thin mucilage. On filtering and pouring the filtrate into rectified alcohol, well shaking it, the arabin separates as a white pasty mass. It must be placed on filter paper and washed with alcohol (not methylated spirit) until the washings are free from water and the alcohol comes off as pure as it went on. Allowed to dry, the mass (other than the edges of the surface) will be a perfectly pure white powder. Though troublesome and expensive to prepare in consequence of the quantity of alcohol required, a little of it goes so far that practically it costs little.

For use the arabin should be dissolved in distilled water to any required consistence, and passed twice through filter paper previously washed with distilled water. It may then be placed on the slips, drained, allowed to dry, and the slips put away for use. In this condition and with ordinary precautions it may be preserved indefinitely.

Mounting Diatoms in Substances of High Refractive Index.—In confirmation of Mr. J. W. Stephenson's views on this subject,‡ Professor Hamilton L. Smith § reports that slides of *Amphipleura pellucida*, *P. angulatum*, and *Rhizosolenia styliformis*, mounted in monobromide of naphthaline (ref. ind. = 1·658) by E. Weissflog,‖ show that there is very little difference, in regard to the visibility of such

* See Amer. Mon. Micr. Journ., ii. (1881) p. 49.
† Journ. Quek. Micr. Club, vi. (1881) pp. 199–200.
‡ See this Journal, iii. (1880) p. 564.
§ Amer. Mon. Micr. Journ., ii. (1881) p. 49.
‖ See this Journal, *ante*, p. 151.

transparent diatoms, between dry mounts and those in monobromide. The markings of *P. angulatum* are almost invisible in balsam, but in the monobromide they are as readily seen as on the dry frustule, and also the same peculiar colour of the dry valve. *Amphipleura pellucida* is quite as distinct and easily resolvable as in a dry mount. Herr Weissflog adds that the distinctness of the diatoms as compared with the balsam mounts is very great, and is especially noticeable in *Rhizosolenia*.

Mounting Marine Algæ.*—The Rev. J. D. King says that the best medium for preserving the colour, either of marine or fresh algæ, so far as he has tried it, is a preparation suggested by Dr. Munson, of Otisco, N.Y.: chloral hydrate, 15 grains; water, 2 ounces.

The tendency of this fluid is to make objects preserved in it more transparent; but he has slides of green algæ mounted a year ago, which yet retain the brilliancy of living colours, and appear in striking and favourable contrast with those mounted in other media. It needs a further trial before pronouncing safely upon its merits, but he believes it to be worthy the attention of algologists.

Mounting Starches.†—Mr. E. Hunter considers that the method described at page 536 is not a good one, as heat alters the form of all starches. When required for polariscope objects, thin dammar and thin balsam are perhaps the best media, used cold and left to harden spontaneously. By this, wheat-starch and many others which do not polarize under ordinary circumstances show well. For ordinary examination, weak solution of ammonia is one of the best media.

It is also pointed out ‡ that an excess of heat will cause the granules to burst and disappear.

Mounting Opaque Objects with Beeswax.§ — Mr. H. Morland gives some suggestions for mounting opaque objects.

He melts down in an oven bleached beeswax (in cakes) with ultramarine or vegetable black, stirring the whole well together. Too much ultramarine must be avoided, as it will crystallize out on the surface of the wax. The blue wax gives a most pleasing background for dead-white objects, and the effect is enhanced by illuminating the wax from beneath.

The wax is melted in a cell on the slide over a spirit lamp, when it will form a cup-shaped bottom. It should be cooled quickly by placing the slide on metal or marble. The objects are fixed not by any cement, but by simply placing the slide upon a block of iron heated to about 140° F. If the object is large it may require to be slightly pressed into the wax. The objects appear by this method to be merely laid on the surface of the wax, and there is no danger of an objectionable "wall" ever appearing round the object if the cover has been hermetically sealed with the wax (using white cement afterwards).

The "wall" is generally caused either by the background not being sufficiently dry or by the vapour of the solvents of the cements

* Amer. Journ. Micr., vi. (1881) p. 58.
† Sci.-Gossip, 1881, p. 135. ‡ Ibid., p. 160.
§ Journ. Quek. Micr. Club, vi. (1881) pp. 196–8.

used for fixing the cover passing under it and re-dissolving the background, a remedy for which is to employ a background having a solvent different to the cement used for fixing the cover.

Dry Mounting.*—Mr. F. French has contributed to the Postal Microscopical Club a slide mounted in a style which promises to be useful for certain kinds of opaque objects which will bear occasional exposure to the dust and moisture of the air, and which are best viewed without the intervention of a cover-glass. The slip is composed of cardboard, cut to 3 × 1 inches, the required thickness in each case being obtained by building up a sufficient number of thicknesses, gummed together. The centres are punched out as from the paper covers for glass slips, and the object is fastened at the bottom of the cell thus formed, either upon mica fastened at the bottom of the cell, or upon a bottom card not punched like the rest. The object is covered by a rectangular brass sliding-plate below the upper card, the card next below being cut away to receive it and to allow it room to slide entirely away from sight when desired. A pin-head is rivetted and soldered into this brass plate, and projects through the upper card, appearing near the right end of the finished mount, through a longitudinal slot that permits it to be pushed toward or from the other end of the slide, and thus to carry the brass plate over the object or away from it. The whole mount is finished by covering with paper in the old style.

Semper's Method for Dry Preparations.†—Herr Semper recently exhibited to the Würzburg Society some zoological and anatomical preparations which had been prepared by a new method for dry preservation.

After being hardened in a solution of chromic acid, the objects are placed in alcohol to remove the water, and afterwards steeped in oil of turpentine and finally dried. The tissues whilst drying are permeated by innumerable small air-bubbles, and in consequence the preparations retain their original form without sensibly shrinking, whilst in colour they assume a white tint similar to that of a gypsum model. The finished preparation, which is almost pure white, and which possesses a firm leathery consistency, may be painted with colours in parts as may be required for teaching purposes. The preparations produced were partly complete animals—mussels, Annelida, &c.—with the viscera of various vertebrate and invertebrate animals. A preparation of a cat's eye showed that, after drying, the position of the parts—the lens, ciliary processes, &c.—underwent no change. A microscopical preparation of brain treated on this method proved that still simpler microscopic relations were retained after the drying, and —particularly with carmine colouring—could be distinctly recognized.

Herr v. Kölliker pointed out the advantage to be derived from this method, especially the possibility of adapting the preparations for special demonstration by painting.

* Amer. Natural., xv. (1881) p. 346.

† Verh. Phys.-Med. Gesell. Würzburg, xv. (1881) SB. ix.

Talc for Cover-glasses with High Powers.—Mr. W. S. Kent found * that in using the high-power objectives necessary for the examination of the minute collar-bearing Flagellate Infusoria, the chief obstacle was presented by the necessity for very thin cover-glass, which causes both inconvenience and loss of time on account of its extreme brittleness. Where the objects under examination are attached to more solid substances, such as the stems of water-plants, this rigidity and brittleness of the cover-glass hampers progress in a most provoking manner, and materially restricts the limits of clear vision.

The unsuitability of ordinary cover-glass for such investigations led the author to provide a substance that has been productive of the most satisfactory results. This was the ordinary talc, formerly universally employed by microscopists, and now extensively used for gaselier shades. This, with a little practice, may be split into laminæ of such extreme tenuity that they may be blown away with the lightest breath, while for perfect evenness and transparency they will compare favourably with the finest manufactured glass. With the employment of these talc-films the investigation of Infusoria with the $\frac{1}{16}$, $\frac{1}{25}$, or even the $\frac{1}{50}$-inch objectives becomes, Mr. Kent says, a comparatively easy task. The material possesses the further considerable advantages of bending readily and permitting the objective to be brought close down on the more remote objects in the field, while it may be cut with the scissors to any required size or shape.

Micrometrical Researches on Contracted Muscle.†—Professor T. W. Engelmann publishes an interesting series of measurements, illustrating the relative lengths of the principal constituents of muscular fibres during contraction. His observations were made chiefly on beetles. They confirm and much extend, from a physiological point of view, the histological results of Foettinger. ‡ Against Ranvier, Engelmann maintains the superiority of insects to vertebrates for these studies. Every student of the more minute phenomena of muscular action will read through the whole of this short paper, with its tables too numerous for quotation.

Prismatic Action of certain Microscopic Objects. §—The colour-changes presented in the Microscope by various substances (chiefly mineral) of uneven surface, when immersed successively in liquids of different refracting power, have been made by Herr Maschke the basis of a method of distinguishing substances. Such changes may be had, e. g. with small glass particles, observed in water, in oil of almonds, and in mixtures of the latter with oil of cassia. The dark and the bright parts of the image show different series of colours. That the effects are simply due to prismatic action of the object appears from the fact that they may be got without the Microscope, by looking through a tube at a piece of rock-crystal in water, &c.

For mineral objects Herr Maschke used five liquids—amylic

* Kent's 'Manual of the Infusoria,' i. (1880) pp. 115–16.
† Pflüger's Archiv, xxiii. (1880) pp. 571–90.
‡ See this Journal, iii. (1880) p. 612.
§ Wied. Ann., No. 12. See 'Nature,' xxiii. (1881) p. 398.

alcohol and glycerine, besides the three just named. By various mixtures of these a series of liquids is obtained, giving any desired index of refraction from 1·333 to 1·606. (Coloration begins when the refraction of the liquid is near that of the object; when the former greatly exceeds the latter a certain stability of colour appears.) The method is not applicable to bodies opaque in the Microscope, or having too strong colours of their own; nor yet to bodies having a greater index of refraction than oil of cassia. It may, too, prove difficult sometimes to find a liquid sufficiently indifferent to the object. Herr Maschke indicates how the refractive indices of substances may be compared by his method, and (a more difficult task) numerically determined. He also gives a number of his own determinations.

Carpenter's 'The Microscope and its Revelations.'*—The sixth edition of this book has just been issued. It is revised, and brought down to the present date by numerous additions, including descriptions of the more recent forms of microscope-stands, of swinging substages, oil-immersion objectives, and additional accessory apparatus, and the chapter on preparing, mounting, and collecting objects has been re-written.

In the sections relating to Protophytes, much new matter has been introduced in regard to the *Schizomycetes* or *Bacteria*, the *Myxomycetes*, and other organisms which occupy the border-ground between vegetable and animal life. To the Protozoa large additions have been made, under the heads *Monerozoa*, *Rhizopoda*, *Infusoria* (especially the *flagellate* and *suctorial*), and *Radiolaria*; and the section on *Sponges* has been entirely re-written. Some additions have also been made in regard to the applications of the Microscope to geological inquiry.

Three important points of microscopical optics are dealt with for the first time in any English treatise on the Microscope.

1st. An account is given of the modern theory of the estimation of aperture, in regard to which it is pointed out (p. 854) that "Professor Abbe's investigation has made it clear that the aperture of an immersion objective may exceed the maximum of that of a dry objective."

2nd. Professor Abbe's diffraction experiments are explained in detail, of which Dr. Carpenter says (p. 188): "We thus have now for the first time the scientific *rationale* of the fact which has long been practically known, the relation of the 'resolving power' of objectives to their angle of aperture."

3rd. With respect to wide-angled objectives, Dr. Carpenter says (p. 191) that "it is clear that the representations of minute structure given by objectives of widest aperture are more trustworthy than those given by those of narrower."

We have noted a few errata for the next edition:—

P. 18: Although Amici, and those who succeeded him, failed to appreciate the importance, as regards larger apertures, of increasing the refractive index of the immersion fluid (first embodied in homogeneous immersion), he should nevertheless be credited with

* 882 pp. (26 pls. and 502 figs.).

the original suggestion not only of water for immersion lenses but of oil also, the dates being: *Oil immersion*, Amici, 1844; Oberhäuser, 1845; Wenham, 1870.* *Homogeneous immersion:* Stephenson, 1878.

P. 33: Professor Riddell should be credited with the original invention of the stereoscopic binocular.

P. 191: The expression "angular aperture" (here and at other places in the earlier parts of the book) should be replaced by "aperture," as a synonym for which it is in fact used by the author, "angular aperture" (and its equivalent "angle of aperture") being, as shown by Dr. Carpenter at p. 852, *one* of the factors of aperture.

P. 193: The quotation "minute details are concealed or destroyed till the aperture is sufficiently reduced," should be omitted, as it conflicts with the author's own more correct view, quoted above, that minute details are more perfectly shown by objectives of widest aperture.

The statements at pp. 193 and 196–7 that there is an inherent incompatibility between good definition and large aperture should be deleted, as it is now known both from theory and experiment that the definition of objectives of the widest apertures (1·47 out of a possible 1·52) is as perfect as with those of less aperture. The wider the aperture of an objective, the greater the technical skill which is required on the part of the practical optician; but the notion that as the aperture of an objective is increased its defining power must necessarily, either on theoretical or practical grounds, be impaired, happily belongs to a closed chapter of microscopy.

It may be safely said that there is no book in the English or any other language which more completely combines all that the amateur worker with the Microscope requires.

The Microscope and the Origin of the Anatomy of Plants.†—Dr. W. J. Behrens, in a paper under this title, gives an historical sketch of the researches of the early vegetable histologists, more especially Cesalpini, Malpighi, and Grew.

The paper also contains a short history of the simple and compound Microscope, terminating with the achromatic Microscope, the invention (or rather "construction") of which is—following Harting—put as early as 1807 by Van Deyl, a Dutchman, afterwards improved by Selligue, Chevalier, and Amici between 1820 and 1830. Van Deyl's objective was made of two biconvex crown-glass lenses, with an intermediate biconcave of flint glass. Such an objective had, of course, a great amount of spherical aberration.

Huberson's 'Journal de Photographie et de Microscopie.'—The first series of this journal (6 vols.) was exclusively devoted to photography, but last year a second series was commenced under the above title, with the intention of including also Microscopy, "at first elementary and restricted to the more ordinary notions, then more advanced, and finally as complete as the competence of the editor and the taste of the readers will allow." The combination of photography

* See this Journal, ii. (1879) p. 490.

† 'Gaea,' xvi. (1880) pp. 480–9, 536–43, 675–80.

and microscopy is justified on the ground that "founded on optics and on the observation of objects of nature or of human art, they are in close connection, each requiring only an easy apprenticeship for those who are already familiar with the other."

The first volume (12 Nos., July–December) contained 84 pages, but in future one part of 16 pages will be published quarterly, the saving thus effected being applied to creating and maintaining a gratis circulating library for the subscribers.

"Société Francaise de Microscopie."—The title-page of the first volume of the preceding journal announced that it was the "Bulletin de la Société Française de Microscopie," and we were for the moment under the impression that a Microscopical Society had at last been established in France. It appears, however, by an announcement in the journal that the constitution of the society is a novel one, as it consists simply of the subscribers to the journal, who are formed by the editor into two groups, one being called the "French Society of Microscopy," and the other the "Photographic Society of France," each with a central group in Paris and local groups wherever the number of subscribers is sufficient.

Of the constitution of the society only the 1st and 3rd articles of the statutes are at present published:—

"Art. 1. There is founded, under the name of the "Société Française de Microscopie," from among the French or foreign subscribers to the 'Journal de Photographie et de Microscopie' who assent to these statutes, a society for observation, for communications, and exchanges, having Microscopy for their object. It is administered by the director of the journal, who bears the title and performs the duties of secretary of the society.

"Art. 3. The members of the society pay neither entrance fee nor periodical subscription. Nevertheless, each of the groups of which the society is composed may impose useful expenditure on the group or on the society (!). This expenditure can only be voted for a year."

Micrographical Mineralogy.—Under this title the French Ministry of Public Works has published* a *livre de luxe*, in 4to, with 509 pages and 55 plates, by MM. F. Fouqué and A. M. Lévy. There are opening chapters on the "utility of the microscopical examination of rocks," and on the "history" of such examinations (referring more especially to those of Leeuwenhoek in 1690, Baker and Ledermuller in 1764, Daubenton in 1794, Dolomieu and Fleuriau de Bellevue in 1800, and others since that date), with directions for "preparing material," on Microscopes for petrological work, and several chapters dealing very exhaustively with the optical properties of minerals. These are followed by directions for the qualitative analysis of rocks, and for extracting elementary minerals from rocks, the first part concluding with an explanation of the deformations and imperfections found in the minerals. The second part (pp. 147–475) is occupied with a detailed description of the various minerals, commencing with quartz. A copious bibliography of 27 pages is appended.

* Part of the 'Mémoires pour servir à l'explication de la Carte Géologique détaillée de la France.'

The plates, most of which are coloured, represent the different minerals described in the work as seen under the Microscope, i. e. not isolated but in their natural association in rock sections. These plates are upon a novel and ingenious plan. To indicate each particular mineral in the sections would ordinarily require the use of letters or numerals, interfering with the appearance of the plates. This is avoided by attaching to each plate (at its upper margin) a piece of transparent paper the size of the plate, containing the *outlines* of the different minerals shown. These outlines being exactly superposed on the plate, and being identified by figures referring to an explanatory table giving the names of the minerals, any one can be at once identified by allowing the transparent sheet to cover the plate.

Some of the plates are "photoglypts" from sections under the Microscope. In all the plates the principal planes of the Nicols when crossed are supposed to be parallel to the margins of the paper. When not crossed the principal plane of the polarizer is supposed to be vertical. The colours of polarization are those shown by the ordinary thickness of the authors' slides, viz. ·01–·03 mm.

Stirling's Practical Histology.*—This book is divided into two parts—"Introduction" and "Practical Work."

The first (38 pp.) contains histological requisites, general directions on the use of the Microscope, including making drawings, preparing tissues, cutting sections, staining, mounting, and injecting.

The second part is arranged under forty-nine separate headings, commencing with blood and ending with the umbilical cord. Each subject is dealt with under distinct sections, "preparation" and "examination," the latter under high (300) and low (65) powers. The arrangement of this part of the book typographically and otherwise is exceptionally excellent. Another special feature consists in the plates, in which the main features of the chief sections are indicated in outline, it being left for the student to fill in the details, the leading parts of which are indicated in the text. The frontispiece is so filled in with colours as an example.

Dr. Klein complains † that the author has not acknowledged his indebtedness to the 'Atlas of Histology' and other books.

* Stirling, W., 'A Text-book of Practical Histology, with Outline Plates,' lvi. and 130 pp., 31 pls. and 27 figs. (4to, London, 1881.)

† 'Nature,' xxiv. (1881) p. 163.

C. Lemnæ. Inhabits the large intercellular spaces of the parenchyma of *Lemna trisulca.* Cells usually spherical or elliptical; that part of the germinating zygozoospore which remains outside the epidermis becomes a spherical head of cellulose.

Endosphæra. Each cell breaks up by repeated bipartition into a number of daughter-cells surrounded by a cell-wall, out of which the spherical zoospores are formed by further bipartition. On escaping, those from the same mother-cell conjugate, and, like those of *Chlorochytrium*, penetrate the living tissue of the host. The zoospores are formed only in the spring; the new generation takes a full year to mature.

E. biennis. Inhabits the intercellular spaces of the subepidermal parenchyma of leaves of *Potamogeton lucens.* Cells usually spherical; the part of the germinating zygozoospore which remains outside the epidermis dies off quickly.

Phyllobium. At the time of maturity the green protoplasm of each cell is differentiated into cylindrical or spherical portions, which become transformed into smaller ones, and coalesce to form zoospores. These are of two sizes, macrozoospores and microzoospores; the resulting zygozoospores penetrate the stomata of the living or dead leaves of flowering plants. Each cell takes a year to mature.

P. dimorphum. Inhabits the leaves of *Lysimachia nummularia, Ajuga, Chlora,* &c. The zygozoospores put out germinating filaments, which grow in the vascular bundles of the leaf-veins into branched green tubes; the protoplasm of each of these tubes congregates into a spherical or elongated resting-cell, which hibernates, giving rise to sexual zoospores in the next summer. According to external circumstances the development of the germinating filament varies greatly; it may be quite rudimentary, when small resting-cells are formed without any filaments, which give rise to non-sexual zoöspores.

Scotinosphæra. When mature the green protoplasm of each cell is differentiated into cylindrical or spherical portions; these coalesce, with the elimination of a red granular substance, into a single spherical mass of protoplasm; this divides by repeated bipartition, the granular substance being again absorbed, into zoospores, which are non-sexual, and penetrate the dead tissue of the host. The course of development occupies a year.

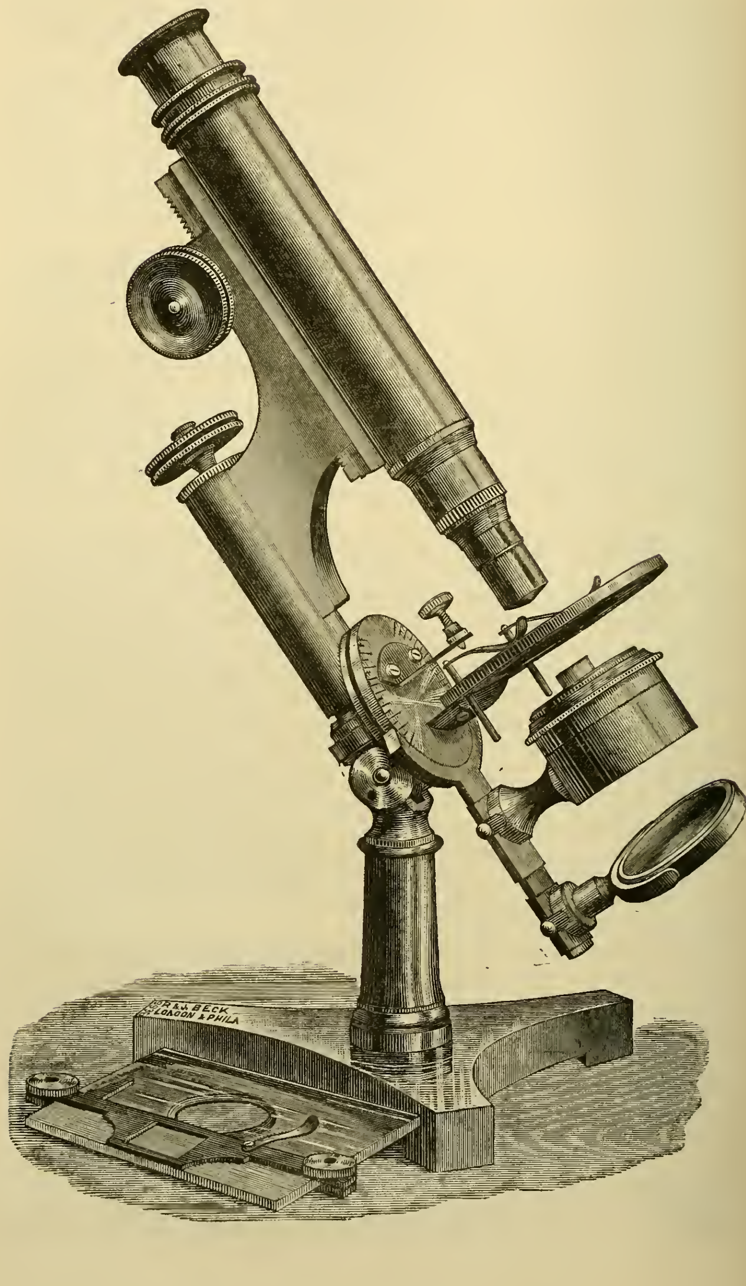
S. paradoxa. Inhabits dead or dying tissues of *Hypnum* and of *Lemna trisulca.* Cells usually spherical; zoospores fusiform.

MICROSCOPY.

α. Instruments, Accessories, &c.

Beck's "Ideal" Microscope.—In this instrument (shown as a monocular in Fig. 166) the *stage* is of very thin and stiff brass with

Fig. 166.



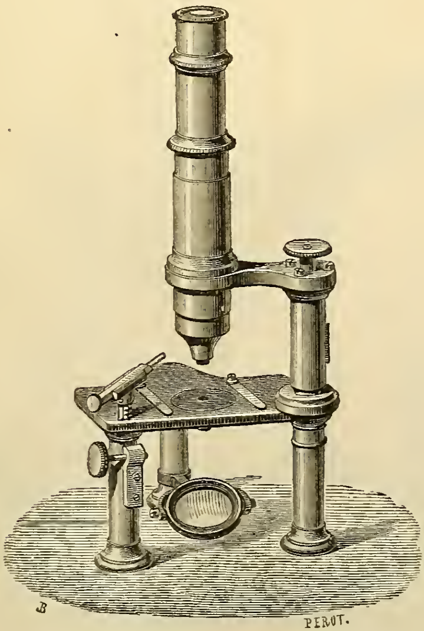
a large opening, and provided with reversible spring clips so as to attach an object to the under side if required. To the stage can be adapted either a circular stage-plate of thin sheet brass revolving concentrically, or the glass stage-plate shown in the figure, with brass object-carrier, and allowing 1 inch of movement in all directions.

The mirror and substage slide upon a *swinging tail-piece*, the latter being attached to a graduated circle, and allowing wide range of motion above and below the stage.

The body draws out to the standard length (10 inches), and takes full size eye-pieces. It has an adapter for the broad-gauge screw. When fully extended it is 15 inches in height, or can be reduced to 11 inches.

Cosson's "Dissecting" and "Observing" Microscope.—This (Fig. 167) can be used either as a simple or compound Microscope. It consists of a stage, 13 cm. wide, supported on three pillars. In

Fig. 167.

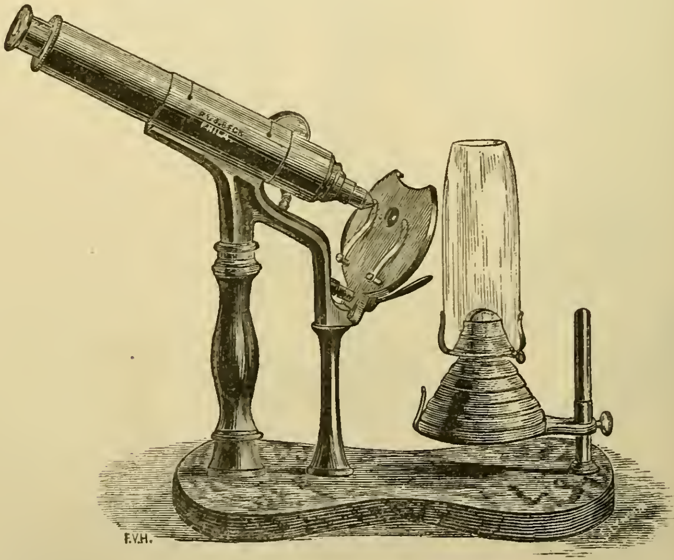


one of the two anterior pillars is a vertical support (raised or depressed by rack and pinion), carrying a sliding arm for the doublets, &c. The other pillar supports the elbow-piece to which the compound body is fixed. The vertical part of the elbow-piece consists of two tubes forming the ordinary Continental fine adjustment, and the whole can be firmly fixed by a tightening screw, or can be turned aside, or removed altogether, when it is desired to use the instrument as a simple Microscope. The mirror is attached to the third pillar.

Holmes's Class Microscope.—This instrument (Fig. 168), the design of Dr. O. W. Holmes, of Boston, U.S.A., is substantially a modified form of Beale's Demonstrating Microscope, except that the tube is not in a horizontal but in a suitably inclined (fixed) position. The wooden pillar on the left forms the handle for passing the instrument round the class. The coarse adjustment is effected by sliding the body through the outer split tube. The height of the instrument is about 12 in., and the size of the base (on which it stands for ordinary table use) 12 × 4 inches.

A special peculiarity is in the fine adjustment, which is effected by moving the stage. For this purpose the stage is suspended by its lower edge to a metal hinge. A somewhat coarse-threaded screw attached to the limb, and having a strong spiral spring coiled round

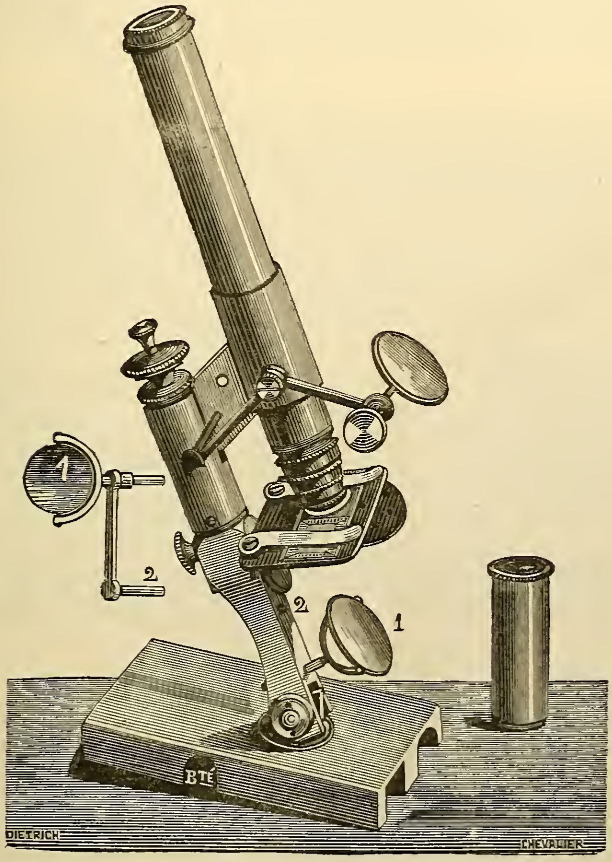
Fig. 168.



it, passes through the stage, and is acted upon by the nut with lever-arm seen beneath. The lateral movement of this lever-arm in one direction causes the stage (which is held between the spiral spring above and the nut beneath), to tilt up from the hinged joint, the spring forcing the stage back again when the lever is turned in the reverse direction. The motion is therefore not strictly at right angles to the optic axis, but for low-power work this is hardly of consequence. In lieu of a condensing lens for opaque illumination, a mirror with three arms, joined by ball-and-socket movements, is attached to the limb. The ring which carries the lamp can be variously adjusted on the standard, to suit the convenience of observation.

Pocket Microscope.—Figs. 169 and 170 show a compact form of compound Microscope (of anonymous French origin) which may be commended for its portability.

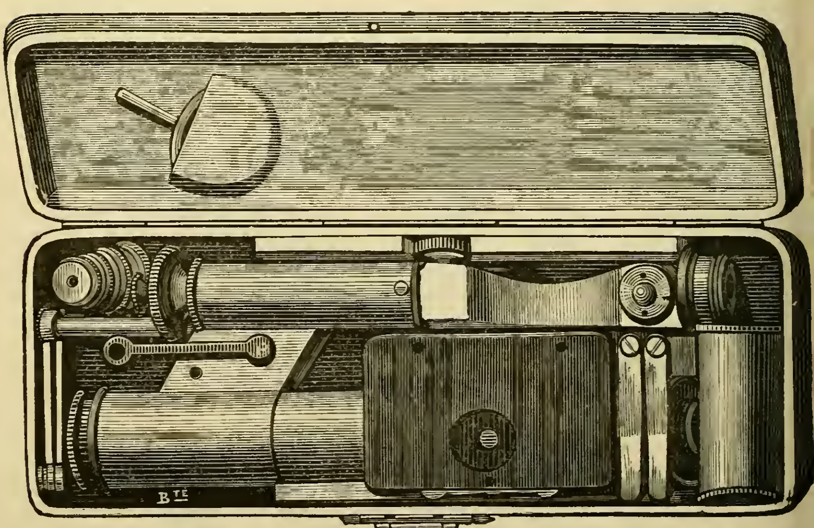
FIG. 169.



The base is a substantial metal tablet upon which the instrument is screwed (Fig. 169). A cradle joint just above the base permits inclination, and in all positions the Microscope is quite steady. The coarse adjustment is effected by sliding the tube and the fine adjustment by the usual screw acting against a spiral spring in the hollow limb, as generally adopted in Continental models. The draw-tube is graduated. The mirror (1) can either be used in the optic axis as shown *in situ*, or an additional elbow-piece (2) fitting into the hole (2) immediately below the stage can be made use of for giving some range of obliquity. A condensing lens for opaque illumination, fitted with jointed arms, can be attached to the side of the tube, and a revolving plate of diaphragms beneath the stage.

For convenience of packing the objective is removed, the draw-tube closed, and the optical body drawn up the sprung-socket; the milled head shown behind the limb is then partly unscrewed, allowing the stage to be turned laterally a quarter-turn, so that it lies parallel with the limb, the optical body being slid down again as far as it will

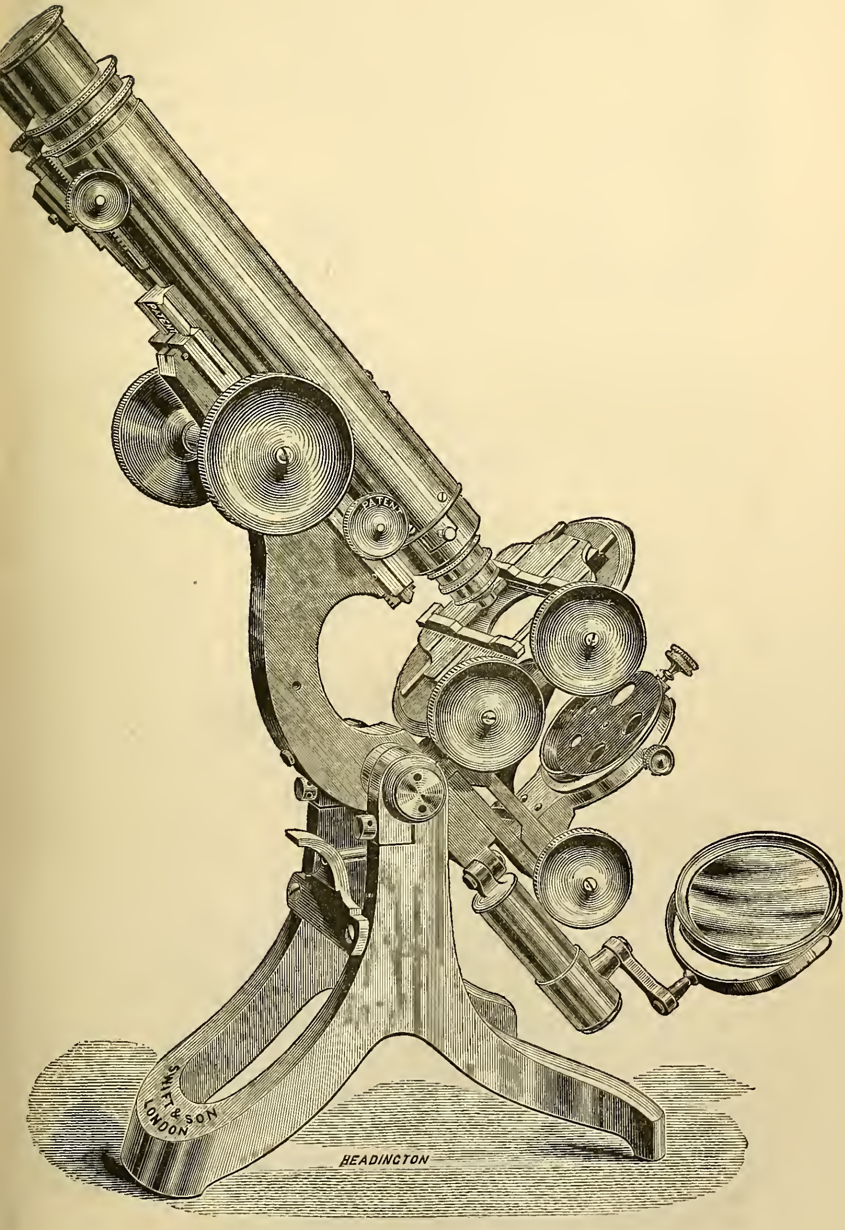
Fig. 170.



go. The mirror and condensing lens are also removed, and the base unscrewed, inverted, and placed in the travelling case, the under surface—shaped in the casting—forming a secure packing for the instrument as shown in Fig. 170. The whole is enclosed in a leather-covered box $7\frac{1}{2} \times 3 \times 1\frac{3}{4}$ inches (about the size of a cigar-case), which can be used as the foot, the Microscope being screwed to the lid instead of the metal base, if it is not desired to be encumbered with the latter on excursions, &c.

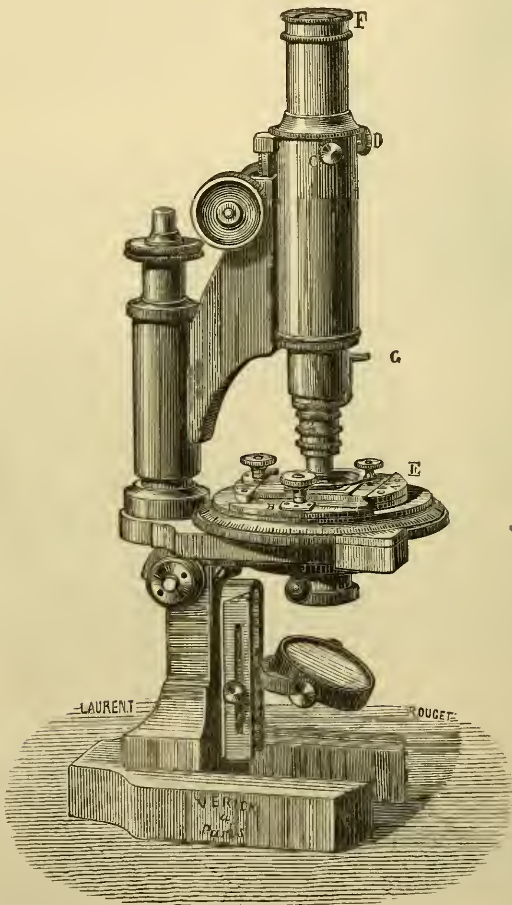
Swift's "Challenge" Binocular Microscope (C).—This form of stand (Fig. 171)—the type model of Messrs. Swift and Son—has had their fine adjustment (described *ante*, p. 296) adapted to it, in which

Fig. 171.



the lifting power is central to the line of motion, thus preventing any tilting. A new mechanical stage of extreme thinness has also been added, the decrease of thickness having, it is claimed, been obtained without any reduction of the solidity possessed by the former stage, as it will bear manipulation of the movments and ordinary touch of the fingers without showing any signs of deflection. The stage allows of an inch of rectangular motion.

Fig. 172.



Verick's "Goniometrical Microscope for Mineralogy."—The general design of this instrument (made in 1879) is shown in Fig. 172, but the following specialties may be noted:

The *mechanical stage* (E′, Fig. 173 and E, Fig. 172), which is attached at pleasure to the ordinary stage (shown in Fig. 174 E) when the clips are removed, appears to be an anticipation in principle of those of Tolles and Watson* recently introduced, the rectangular movements being controlled on the surface by two milled heads acting entirely within the circumference. B (Fig. 173), and the opposite symmetrical piece are attached to the fixed bottom plate and have V-shaped grooves between which the movable plate A slides. Rackwork is cut on the lower edge of the latter, which is acted upon by a pinion (milled head shown at B) giving about one inch of motion. The plate A has in the same way two opposite symmetrical pieces similarly grooved, and an upper movable plate slides between them by rack and pinion motion (milled head shown on the left) acting at right angles to the former motion. This upper plate is provided with an angle-piece serving as a stop for the object, and a sprung "horse-shoe" clip for holding the object in place. At A and B are graduations for use as finders. The bevelled edge of the *rotating stage* (Fig. 174) is graduated, and a vernier is placed on a projecting angular piece for convenience of reading the angle. The diaphragms slide from beneath the stage into a cylindrical tube, and can be used flush with the surface of the stage.

FIG. 173.

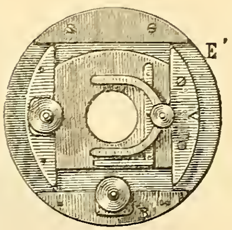
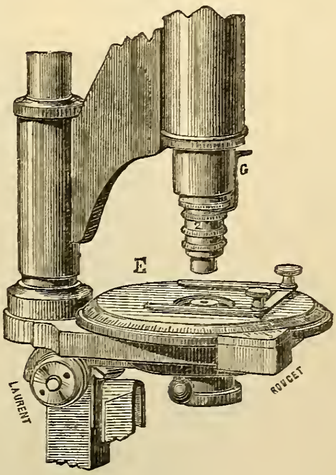


FIG. 174.



The *mirror* can be raised or lowered, and swung laterally by the arrangement shown in Fig. 172.

The eyepiece-tube can be exactly centered by the screws C and D (Fig. 172), which is of advantage in the determination of the polarizing axis in minute crystals.

When the instrument is required for ordinary investigation the eyepiece-tube is replaced by a draw-tube of the usual construction. The mechanical stage is also removed, being held in position by two pegs of brass simply fitting into corresponding apertures in the ordinary stage E (Fig. 174) and the sprung stage-clips are substituted.

The Microscope is provided with a novel arrangement termed an "*extractor*," for facilitating the rapid removal and change of objectives at the nose-piece, shown in Figs. 172 and 174 G, and described *ante*, p. 662.

* See this Journal, *ante*, pp. 116 and 300.

Seibert and Kraft's Dissecting Microscope.—Dr. Carpenter figures this instrument,* which he commends in preference to those forms in which the supports for the hands are attached to each side of the stage, "an arrangement which is subject to the disadvantage

Fig. 175.

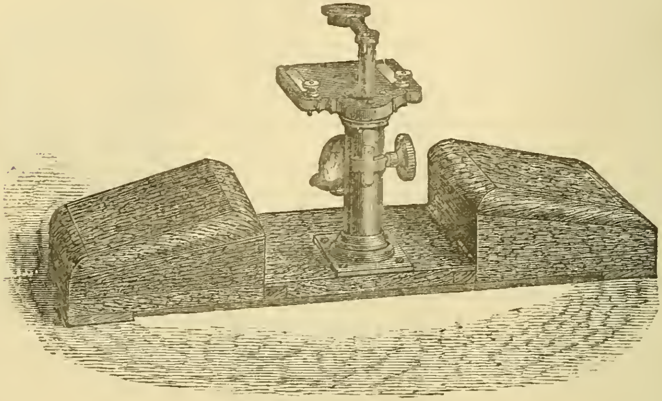
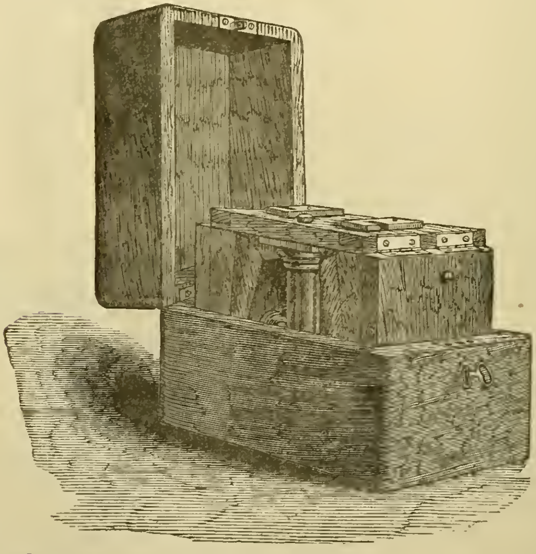


Fig. 176.

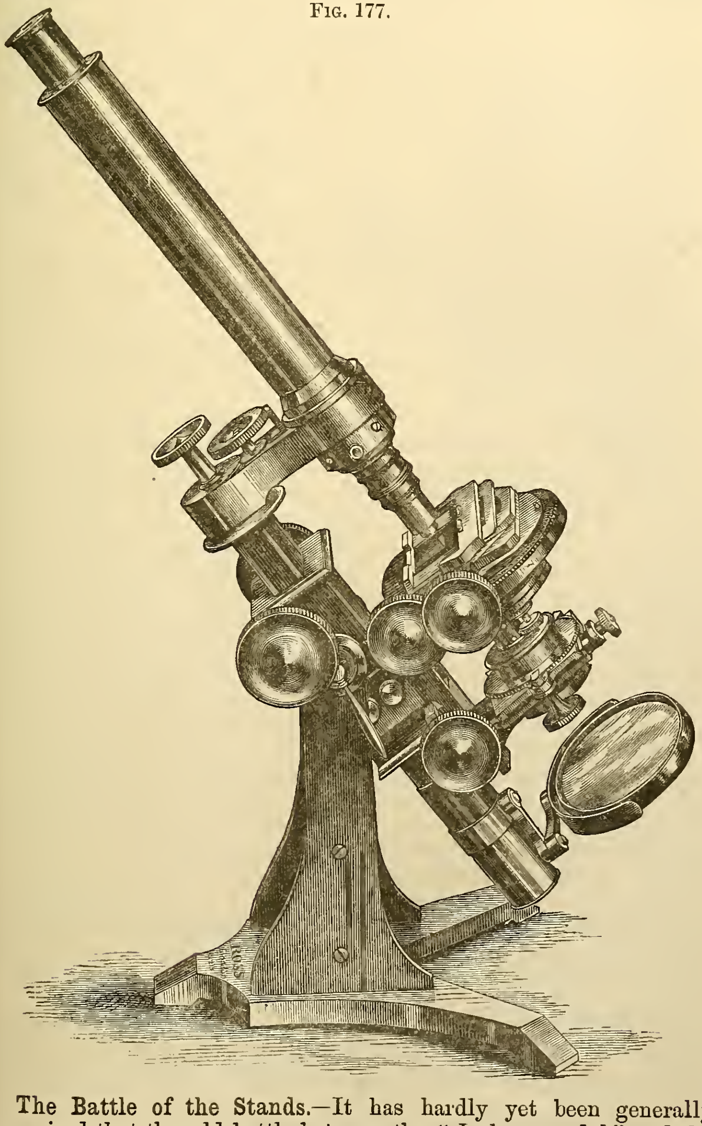


of causing the whole weight of the hands to bear upon the stage so as by depressing it to throw the object out of focus unless the stage be made of extraordinary solidity or be supported in front as well as behind."

* 'The Microscope,' &c., 6th ed., 1881, pp. 54-5 (2 figs.).

Fig. 175 shows the Microscope as opened for use. The oblique wooden blocks, which form the supports for the hands, being hinged to the wooden base of the pillar, can be turned up for portability (as shown in Fig. 176), so that the instrument packs into a very small compass.

FIG. 177.



The Battle of the Stands.—It has hardly yet been generally recognized that the old battle between the "Jackson model" and the

"Ross model" is virtually at an end, in consequence of a discovery which had not been made when the question originally arose.

The advantage of the Jackson model was the increased steadiness which was obtained by the support given to the body-tube throughout the greater part of its length, a support which was wanting in the Ross model.

The advantage of the Ross model consisted in the greater efficacy of the fine adjustment, which could be worked by a relatively long lever, instead of being confined, as in the Jackson model, to a very short one in front of the lower end of the body-tube.

The invention of the method of fine adjustment by which the whole of the body-tube is moved and not merely an inner tube, carrying the objective at the end of the body, at once deprived the Ross model of the advantage which it previously possessed, and left the Jackson model necessarily the preferable form.*

The Ross model is no longer made by the firm whose name it bears, but it has in its day enjoyed so much celebrity, that in order to record it for future reference we print here a figure of it (Fig. 177) which has not previously appeared in the pages of this Journal or its predecessors, other than in the advertisement covers, which are but rarely bound up.

Fine Adjustment by the Eye-piece.—Professor L. Ranvier recommends† that the eye-pieces of monocular instruments should be capable of being moved up and down in the draw-tube for the purpose of focussing with high powers. The difficulty of observing with such powers and the fatigue which results are due in great part to the difficulty of exactly focussing the object. The eye of the observer attempts to complete what is wanting in the instrument, and to accommodate itself as much as possible, and it is this fatiguing effort of accommodation which is avoided by the movement of the eye-piece. Apart from the fact that the movement of the eye-piece obviates the necessity for great care in focussing, so as not to displace the image or break the cover-glass, it is a great advantage that with the very exact focus which can thus be obtained it is much easier to determine the superposition of the planes in the case of very small objects—for instance, whether a fibrilla close to a cell passes below or anastomoses with it. As the eye-piece must be very appreciably displaced to very slightly change the point of distinct focus, we "are able to resolve very easily a series of hitherto disputed problems."

The apparatus which Professor Ranvier uses is shown in Fig. 178. It consists of two brass rings *a* and *b*, united by the rackwork *c*, so that the distance between the rings can be increased or diminished. The ring *a* is fitted to the top of the tube of the Microscope, the eye-piece is placed in *b*, and by turning the milled head *d* the eye-piece

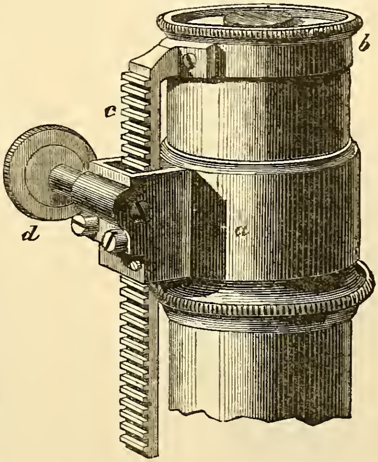
* Dr. Carpenter "feels assured that the principle of supporting the body along a great part of its length (which may be applied in a variety of modes) will in time supersede that of fixing it by its base alone, which is obviously the mode *least* adapted to prevent vibration at its ocular end."—'The Microscope,' &c., 6th ed., 1881.

† 'Traité technique d'Histologie,' Part 1, p. 11. (8vo, Paris, 1875–8.)

can be raised or depressed. With a No. 10 immersion of Hartnack, for instance, a change in the image obtained with $\frac{1}{20}$ or $\frac{1}{50}$ of a turn of the ordinary focussing screw is accomplished only by a whole turn of the milled head *d*.

Mr. J. Deby* has also recently made a somewhat similar suggestion; he says: "When allowing all but adepts in the use of the Microscope to peep through my high-power glasses, I have often felt a certain degree of uneasiness, not to say of alarm, regarding the fate of valuable test-slides, or still more valuable objectives. Many others have no doubt experienced the same discomfort, which I find an easy matter to attenuate to a considerable extent, by focussing from the eye-piece instead of from the coarse or the slow motion. All that is needed for this is a rack and pinion to the eye-piece of considerable length. An inch or two up or down corresponds here to a fraction of a turn of the fine adjustment of the Microscope, so that very little danger exists of any sudden contact with the cover-glass.

Fig. 178.



As soon as an indistinct view of the object is obtained through the ordinary coarse adjustment of the microscope-body, the focus is brought to exactness by means of the coarse motion of the eye-piece without much difficulty. For demonstrations or exhibitions in public, Microscopes could thus be made without the ordinary fine motion."

At the June Meeting of the Society, at which Professor Ranvier's plan was discussed, some objection was made to it† and we have since received the further objections as follows:—

"(1) With a high power of large aperture a slight alteration in the length of the body will spoil the definition.

"(2) There is a difficulty in ascertaining the best focus, and the eye is strained in attempting to help in focussing, particularly in focussing *down*. An object should always be observed at the *longest* focus.

"(3) The alteration in power is apt to be misleading, in examining the upper and lower planes."

In any case we should prefer the mode of raising and depressing the eye-piece adopted with English binocular Microscopes. It should also be noted that to utilize the movement of the eye-piece for accurate focussing, there should be a *normal* position from which *upward* and *downward* motion can be made.

* Journ. Quek. Micr. Club, vi. (1880) p. 165.
† See this Journal, *ante*, p. 715.

Zeiss's Camera Lucida with Two Prisms.—This camera lucida * (Figs. 179 and 180) consists of a rectangular and an equilateral prism, so combined in the mounting that the image of the pencil and drawing paper is totally reflected twice, and is thus viewed erect by the eye looking over the edge of the equilateral prism at the image produced by the eye-piece of the Microscope.

P (Fig. 180) shows the direction of the ray from the drawing-board; after two reflections this ray emerges parallel to the optic axis of the Microscope. As the angle between the two reflecting

Fig. 179.

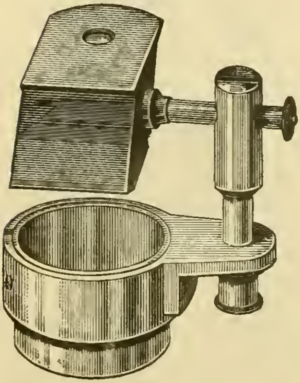
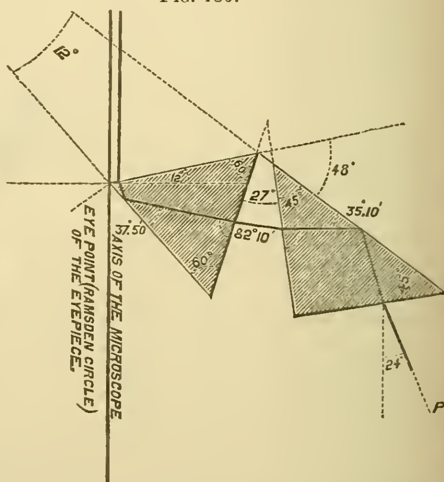


Fig. 180.



surfaces of the prism = 12°, the direction P must always be inclined 24° to the axis of the Microscope. If, in drawing with the prisms, the plane of the paper were horizontal and the Microscope in a vertical position, the drawing would be somewhat distorted, the circular field being projected as an ellipse whose axis would be as 10 : 11. By inclining either the Microscope or the plane of the drawing about 12° the amount of distortion is hardly perceptible. To obtain a strictly similar projection the inclination should be 24°.

The inclination of the upper surface of the equilateral prism (which is supposed = 12° in the diagram) may be varied within certain limits. An angle of 10° to 15° is necessary in order to have total reflection in this prism for all directions within the range of the microscope-field.

The following description of the use of the apparatus is furnished by M. Zeiss:—

"To draw with the prism remove the eye-piece (after exact adjustment of the object) and slide the ring, found under the prism, over the tube of the Microscope, then put the eye-piece again in place.

* This is sometimes known as the "Vertical Camera Lucida," as it is used with the Microscope in an upright position.

The light can fall either on the left or in front. Now turn the ring of the prism to the left, lift the vertical pin sufficiently so that the prism can be placed in a horizontal position over the eye-piece, and push the horizontal pin in so far that the circular opening of the prism is over the centre of the eye-piece. Now place behind the Microscope a drawing-board, or an atlas with the hinge or back touching the foot of the instrument, or about 2 inches away from it, whose upper cover can, by some contrivance placed within it, be inclined about 18°. On this the drawing-paper is to be laid. If the prism has been placed with the horizontal surface so far round the vertical pin backwards that the clear circle visible in the eye-piece, on looking through it from a vertical direction, is about halved by the sharp edge of the prism, we see through the half of this circle which is visible through the prism, not only the object clearly, but also the paper with the pencil. If the further margin of the field of view appears somewhat less clearly on the paper, lift the anterior part of the prism by turning it on the horizontal pin until it is clear, whereupon by depressing the vertical pin the prism is placed as near the eye-piece as possible. In order, however, that both images shall be equally clear it is necessary that both should be equally illuminated. If the pencil-point appears faint and dim, either the paper must be more strongly illuminated by changing the position of the whole apparatus, or the object must be darkened by altering the mirror, and *vice versâ*. Short-sighted people must use a lens when the distance of the pencil is greater than that of their natural vision."

Silver Films for Instruments of the Camera Lucida Class.*—Mr. J. C. Douglas, Secretary and Treasurer of the Asiatic Society of Bengal, in a paper on this subject, points out that what is required in an instrument of this kind is the brilliancy and clear definition of the camera lucida, combined with the simplicity and ease in use, and the cheapness, of the tinted plane glass reflector, with the facility when desired for using two reflections, in order that the reflected image may not be reversed, and he believes these requirements are attainable by the use of silver films on glass.

"These are so highly reflective that two or more successive reflections may be used if desired; by transmitted light the colour of the film is suitable for tinting the glass. The thickness of the film may be regulated according to requirements, a thick film being used when reflection only is required, and a thinner one according to the ratio desired between the reflected and transmitted light. The reflective power of the thinnest film is greatly superior to that of glass. The silver film is applicable to most forms in use, and it may be used not only on plane but on curved surfaces, e. g. a plane concave lens, silvered on the plane side, might be used by a short-sighted person instead of the common plane reflector used in sketching microscopical objects, a slight curvature of the first or second reflecting surface in the camera lucida might be used to render it unnecessary to employ a lens to equalize the sensibly different distances of the images of the

* Proc. Asiat. Soc. Bengal, 1880, pp. 73–6.

object and plane of delineation. The cost of silver films on glass is very trifling, and if taken care of they last for years; a number might be made at intervals, or they might be supplied for a trifling sum by the opticians.

"For many purposes the films might be deposited on thin glass, and varnished or protected by glass, when they would be very durable, and would bear handling. For some purposes the film might be thickened by electro deposition, and removed from the glass. As the films are so cheap, a number of graduated thicknesses might be kept, and a suitable one selected in each case to adjust the relative brilliancies of the reflected and transmitted light; or the films might be applied as the dark glasses usually supplied with the camera lucida, but this seems less simple and convenient than the use of a thicker or thinner film as transmitting reflector. A silver surface may reflect upwards of 90 per cent. of the incident light; a total reflecting prism has been found to reflect only about 75 per cent., or less, the loss being due to reflection at the first surface and absorption; the superiority of the silver surface is evident, particularly when several successive reflections are required. [We understand the fact to be quite the converse, and that the advantage is in favour of the prism.—Ed.] Even if the highest attainable brilliancy be not generally required, still the higher this is, the greater the range of adjustment without alteration of the source of light. The strictest regularity in the film not being essential, suitable films are very readily obtained. With strict cleanliness, pure chemicals, care that the glass is wetted equally in every part by water or alcohol at the moment of immersion in the silvering solution, and care that the solution is properly mixed, i. e. homogeneous, success is readily obtained.

"Professor Govi, of Rome, devised * a form of camera lucida in which a metallic film is used. He simply gilds the reflecting surface of the camera lucida prism with a thin film of gold, and cements to this surface with Canada balsam another similar prism. M. Nachet has adopted this improvement in the construction of various forms of camera lucida. The greater advantages of the silver film are obvious. By the use of silvered glass, instruments of various forms and of large size may be readily constructed for a trifling sum by any ingenious person."

The following is a description of the instruments exhibited at the meeting of the Asiatic Society when the paper was read :—

"1. An ordinary tinted glass reflector for use with the Microscope. The tinted glass usually used was replaced by a piece of glass covered with a thin film of silver. The silvered side is turned towards the eye-piece, and reflects the magnified image. In this form, several reflectors, differing in the thickness of the silver film, should be available for regulating the ratio between the transmitted and reflected light, but a certain thickness of film will be found which is applicable to most purposes, so that change of reflector is seldom necessary.

* See 'Annual Record of Science and Industry,' 1875, p. 144.

2. Camera lucida with double reflection, Fig. 181. The first reflection is from a thick film of silver, the second is from a thinner film. The thickness of the second film may be adjusted as described above. It will be seen that the plane of delineation is seen *through* the second reflector, not past it as in the ordinary instrument. (In the diagrams the thick oblique lines are the silver films, the thin lines the directions of the light, the arrows the objects, and the dotted lines the paper on which the objects are to be drawn.)

FIG. 181.

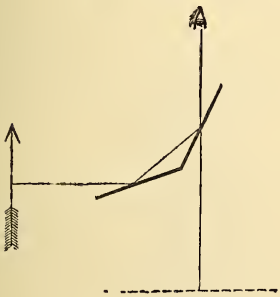
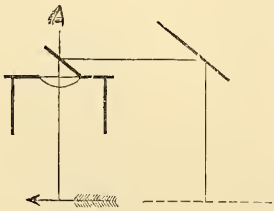


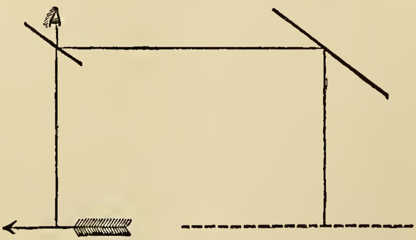
FIG. 182.



3. A form of reflecting camera for sketching microscopical objects, Fig. 182. This instrument being fitted to the eye-piece of the Microscope, the paper and pencil point under the larger reflector appear in the field of the Microscope. The object is seen direct. The second mirror in the instrument exhibited was an inch square. This instrument may be used with the body of the Microscope at any angle, it being merely necessary to place the drawing paper in a plane parallel with that of the microscope-stage. (In the Figs. 182 and 183 the mirrors are represented as parallel; they should usually be slightly inclined to each other, to increase distance between plane of delineation and the object.)

4. Another reflecting camera for sketching small objects is represented in Fig. 183. In the instrument exhibited, the larger reflector was $1\frac{1}{2}$ by $1\frac{3}{4}$ inches and placed 10 inches from the paper; the field was about $4\frac{1}{2}$ inches square. This instrument may be used horizontal or inclined, and it is well adapted for drawing such objects as insects, leaves, shells, &c. If the vertical distances between the mirrors and the object and paper respectively be constant in instruments of this form, the relative magnitudes of object and drawing will obviously vary with the distance between

FIG. 183.



the reflectors. It is evident that by the use of reflectors in instruments of this class, the reflecting surfaces may be larger, and the distance between them greater than if a prism were used.

The above are only examples of the application of silver films to a particular class of instrument; it is evident they offer great facility for giving this class of instrument its maximum development. It is obvious also that silver films are applicable with advantage in many other cases where prisms are used at present, particularly where it is desired to divide a beam of light into two; e. g. if Fig. 183 be turned upside down, and the two eyes of the observer be in the place of the arrow and the dotted line, the diagram represents an arrangement suitable for a non-stereoscopic binocular Microscope, the inclination between the mirrors being varied to suit the distance between the eyes; the loss of light in such an arrangement would be very little, and the brilliancy of the two images might be rendered very nearly equal."

Apparatus for Examining Different Spectra.—Whilst the diffraction spectra can readily be seen at the back of the objective by the unassisted eye on removing the eye-piece, they are better defined and their exact arrangement is much better observed by some addition to the Microscope in the form of either an auxiliary Microscope or a telescope.

In the first case, an objective of low power, screwed into the draw-tube, forms, with the eye-piece, a compound Microscope, which can be focussed to the plane of the diffraction spectra. In the second and more convenient arrangement a suitable combination of lenses is placed *above* the eye-piece, as in Ross's "centering glass," forming a *telescope* which can be focussed upon the diffraction spectra in the same manner, and easily removed to substitute other eye-pieces. This plan is the one used for some time by Mr. Ingpen, whose apparatus consists of a Ramsden "positive" eye-piece (formed of two plano-convex lenses of equal focus with the plane surfaces turned outwards) of $\frac{1}{2}$ or $\frac{3}{4}$-inch focus, sliding in a short piece of tube over the lowest power Huyghenian eye-piece. The quality of the illumination, its centricity or obliquity, &c., can also be readily observed in this manner.

Sorby's Binocular Spectroscope.—This instrument (Fig. 184), made by Messrs. Beck, was originally described in Proc. Roy. Soc., xv. (1867) p. 433, but has not hitherto been figured. It can be used with the binocular Microscope, and for many purposes is superior to the ordinary micro-spectroscope, and gives a larger dispersion. It consists of the following parts (taken from Messrs. Beck's description):—

1st. An object-glass A, specially arranged, screwing into the tube of the Microscope by the outside screw B.

2nd. A series of compound dense glass prisms C, fitting immediately over the object-glass A.

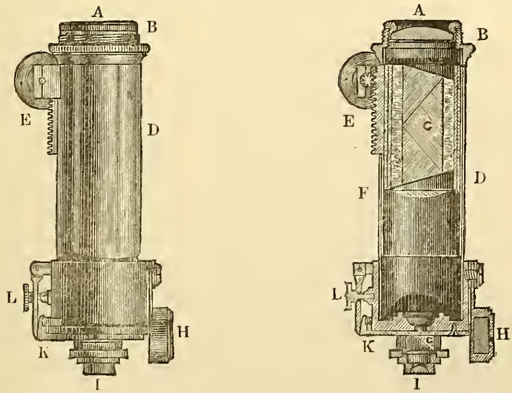
3rd. A tube D, moving up and down upon that holding the prisms by means of rack and pinion E, and carrying the following:—

(*a*) A cylindrical lens F, for lengthening out the spectrum.

(*b*) A small right-angle prism G, sliding in and out of the field of view, which, when slid in, projects over half the field and throws an image of the dark bands in a piece of quartz polarized by means of two Herapathites or flakes of iodide of disulphate of quinine, and termed

(*c*) The "Standard Scale," H. This portion of the apparatus is used when the observer desires to record the position of the absorption bands. The plate of quartz which it contains is cut parallel to the optic axis,* of such a thickness that

Fig. 184.



the line D in the solar spectrum comes between the third and fourth band. It is thus described by Mr. Sorby:—"In order to measure the exact position of absorption bands, &c., seen in spectra, I have contrived a small apparatus which gives an interference spectrum divided by black bands into twelve parts all of equal optical value. It is composed of two Nicol's prisms, or Herapathites, with an intervening plate of quartz about 0·043 inch thick, cut parallel to the principal axis of the crystal, the thickness being so adjusted that the sodium or D line is exactly $3\frac{1}{2}$, counting the bands from the red end towards the blue."

4th. A small lens I, to condense the light from the object. And

5th. A very accurate slit K, one side of which is adjusted by means of the milled head L.

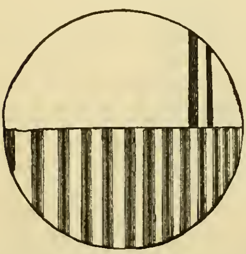
Mode of Use.—Screw the object-glass A into the body of the Microscope; slide the rest of the apparatus on, and turn it round

* It is well known that a plate of quartz cut parallel to the optic axis will, under polarized light, give a series of black bands, the distance between such bands being due to the thickness of the plate of quartz.

so that the sides of the spectrum are seen square or upright, thus , not thus . Adjust the outer tube by means of the rack-and-pinion movement E, so that a clear image of the slit K is visible; regulate the width of the slit by the small milled head L, so that if by daylight the more prominent lines in the solar spectrum are seen. Focus the whole body of the Microscope so that the small lens I just touches the object to be examined. (The small lens merely receives the light from the object and does not form an image of it.)

If it is desired to register the position of the absorption bands under view, push in the little prism G at the side, turn down the small box H containing the standard scale, and throw the light through it. In the field of the Microscope will be seen on the upper half the spectrum of the object under observation, and on the under half an image of the standard scale as under, Fig. 185. If the small right-angle prism G should require to be cleaned, it must be withdrawn steadily, to avoid chipping. The carrier is made with a projecting prong *on one side*, which to a great extent protects the prism; but such protection cannot be put on the other side without stopping the light. A piece of black paper has to be cemented on the back of the small prism G, to stop the passage of any direct light. This can be turned up when the prism requires cleaning, which should be done with a delicate piece of wash-leather or cambric handkerchief. If the cylindrical lens F is removed for cleaning, care must be taken in replacing it that the cell is screwed up so that the two marks on the lens are parallel with the slit, otherwise the definition will be impaired.

Fig. 185.



Fase's Zoophyte Trough, Live Box, or Growing Slide.*—This arrangement, devised by the Rev. H. J. Fase, is shown in plan view with the cover removed at Fig. 186, and in transverse vertical section at Fig. 187. A is a glass plate, 3 inches by $2\frac{1}{4}$ inches, to which is cemented a stout bone or ivory ring B, $\frac{3}{8}$-inch in height, having a thin lining of cork C, cemented to it. D is a shorter tube of ivory or bone, with a broad flange at the top, and closed at the bottom by a disk of thin cover-glass E. This tube D slides freely in B. A narrow slot F is cut in the inside of B, from the top outside, sloping to the bottom inside.

To use the apparatus as a zoophyte-trough, a ring of indiarubber G, cut through as shown at H in Fig. 186, and of a thickness suitable to the object to be examined, is placed at the bottom of B. The object is placed in this ring with a little water, and the cover is then pressed down gently, any excess of water flowing out of the cut in the

* Journ. Quek. Micr. Club, vi. (1881) pp. 249–50 (2 figs.).

indiarubber ring into the box. For use as a growing slide a ring of indiarubber or of gutta-percha tissue is placed as before in the bottom of the box (but in this case the cut in the ring is to be placed as indicated by the dotted lines in Fig. 186); the object to be examined is placed within the ring, and water added through the slot F, which passes into the box outside the indiarubber ring. Water may also be added to supply the loss from evaporation from time to time, through the slot F in the ring B, which slot may be closed by a plug of cotton wool, to exclude dust and prevent evaporation. When it is desired to use the apparatus as a live-box, the indiarubber ring may be dispensed with. The object is placed in the ring B, the cover D pushed in as far as found desirable, and water added if required by the opening or slot F, which may be closed by a plug of cotton wool as before.

Fig. 186.

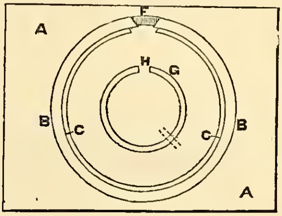
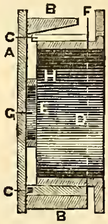


Fig. 187.



The advantages of the apparatus are that it admits of the easy arrangement of the object to be examined; that it is readily cleaned; that as no metal is used in its construction, it allows of prolonged observations being carried on without disturbance of the object; that water, either fresh or salt, may be added from time to time; and that the thin cover-glass permits of high powers being used, and is readily replaced when broken.

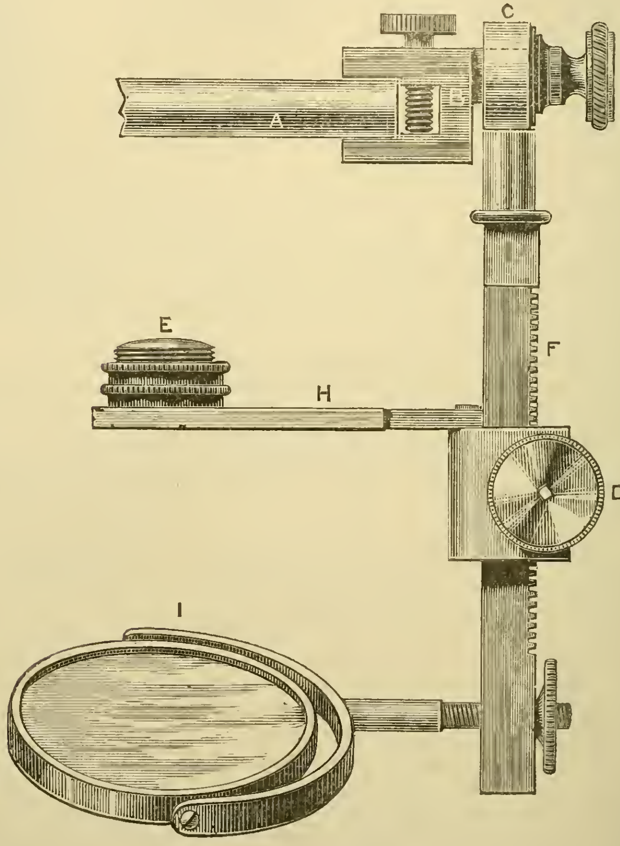
Malassez's Moist Chamber.*—Professor Malassez recommends a graduated moist air chamber. A thick slide has in its upper surface a circular groove 1·5 mm. broad, 1 mm. deep, and 7·5 mm. in internal diameter. It is pierced outside the groove by three or four holes into which are introduced fine screws; the heads are on the side furthest from the observer (but do not project beyond the lower side of the slide). The points are directed upwards and project so that the cover-glass can be laid upon them; the preparation which is to be examined is placed on that part of the slide which is surrounded by the groove, and by putting some water on the edge of the cover-glass, an air-tight space is obtained without the risk of the water coming into contact with the object, as the groove prevents its passing inwards. By removing the screws any required depth can be given to the space within the chamber, with the aid of a pointer for measuring the depth. By this means the chamber may be utilised for counting (e. g. blood-corpuscles) by given units of space, by having a set of ruled micrometer spaces either on the stage or in the eye-piece.

Mackenzie's Swinging Substage.—We briefly alluded, on p. 515, to a simple form of substage devised by Mr. J. Mackenzie, and

* Gaz. Méd., 1879, p. 632. Cf. Zool. Jahresber., i. (1880) p. 25.

referred to the figure of the appliance given in the Journ. Quek. Micr. Club, vi. (1880) pl. xii. Certain modifications have been suggested * which add to its efficiency, and which we here describe with reference to Fig. 188. These modifications are four in number. (1) The application of metal jaws for clamping the swinging bar to the stage at

Fig. 188.



pleasure, instead of the permanent fitting in one position by screws. (2) The *sliding* movement on the arm H, instead of a fixed arm carrying the condenser. (3) Similar sliding movement to the mirror. (4) The rackwork is carried much higher up the bar for greater convenience of focussing the illumination with a condenser of short focal length.

A is a part of an ordinary fixed stage of a Microscope. B, metal jaws clamping upon the edge of A by means of the milled head shown above; the fitting of these jaws is so arranged that the axis at the back, on which the whole bar C swings laterally, is (approximately)

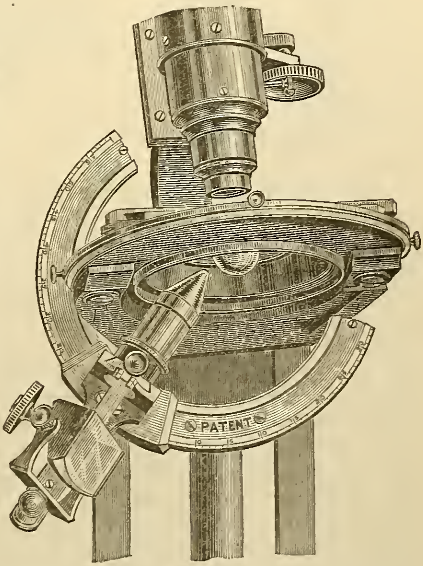
* Eng. Mech., xxxii. (1881) p. 582.

in the plane of the object supposed to be on the stage. The swinging bar C is provided with rackwork F on which the arm H, carrying the condenser E (which might be a 1-inch or 2-inch objective), can be moved up or down by the milled head D. The arm H is fitted to slide for convenience of centering with the optic axis; the mirror I is also made to slide for the same purpose. These sliding movements also permit the use of slightly excentrical pencils, which are found to give increased power of resolution in particular cases. The condenser E can be racked to focus the illumination on the object. The lateral swing of the bar C will then provide the whole range of oblique illumination in altitude concentric with the object, by suitable adjustment of the mirror. The swinging bar also permits the condenser and mirror to be used *above* the stage for "opaque" illumination.

It is obvious that this apparatus admits of application to many of the less expensive forms of Microscope at a very moderate outlay, and that other modifications may be suggested that would add materially both to its efficiency and its cost. We understand that Messrs. Watson have applied a disk at C for registering the angle of obliquity. A centering arrangement with rectangular motions might be advantageously applied on H.

Swift's Radial Traversing Substage Illuminator.—Messrs. Swift have (very advisedly) abandoned the second sector at right angles to the first,* and now issue the instrument in the form shown in Fig. 189.

Fig. 189.



We extract (slightly altered) the following remarks which they make as to the relative value of condensers and swinging substages:—

"This arrangement (Fig. 189) is superior to the ordinary swinging substage, as it does not in any way impair the steadiness of the upper stage, being slid into a dovetailed fitting on the limb of the Microscope, in lieu of the substage which is detached. Beyond this it has the advantage of being light and handy, and the condenser, if necessary, can be brought above the stage for the illumination of opaque objects. We would only, however, recommend this apparatus to those who wish to avoid the trouble of using an achromatic condenser, although this latter piece of apparatus when in

* See this Journal, iii. (1880) p. 867.

skilful hands is by far the best arrangement of the two, the former ingenious contrivance being suitable for one class of illumination only. . . . We do not hesitate to recommend the achromatic condenser as being superior to any other method of substage illumination, for in spite of all that has been both written and said in praise of the swinging substage illumination, the practical results hitherto obtained by it prove that its resolving capabilities have been greatly exaggerated, when compared with the performance of a high angle achromatic condenser."

Kelner Eye-piece and Equilateral Prism as a Means of Illumination.—Mr. James Smith points out that whilst both the Kelner eye-piece and the equilateral prism have long been in use for illumination, the combinations he employs have, he thinks, some novelty, and he thus describes them :—

Fig. 190.

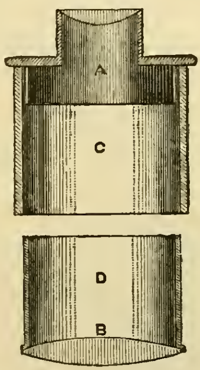
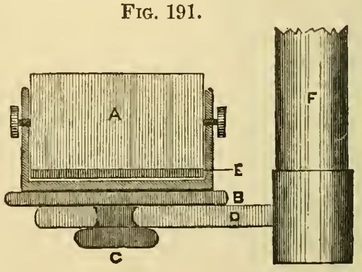


Fig. 191.



"It will be seen from Fig. 190 that I have divided the Kelner eye-piece into two parts, the eye-lens A being in an outer tube C and the field-lens B in another tube D sliding into the former. When the field-lens is upwards and pushed up into the tube C the eye-piece will be in its normal state, and act as an illuminator for high powers (up to the $\frac{1}{50}$), as described and used by Dr. Beale; but when the field-lens is reversed as in the drawing, the two lenses are then considerably separated, a much larger but more softened spot of light is the result, and it can be used advantageously with low powers even down to a 3-inch objective, giving a fully illuminated field.

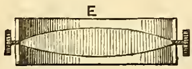
In combination with the eye-piece I use an equilateral prism A mounted as in Fig. 191, turning on its axis and also at right angles to it by means of a circular plate B C. The prism has cemented to it a piece of pale-blue glass E, and the whole slides on the mirror-arm F in the usual way. The equilateral prism is convenient, as taking the light from any side indifferently. When the light from the lamp passes *through* the blue glass it is modified, and a fine white light is obtained more like daylight, and the natural colours of delicate objects such as diatoms and desmids in fresh water are beautifully shown;

the definition also of colourless objects is much improved. When, however, the prism is turned round and the light taken by *reflection* from the coloured glass, a delicate monochromatic light is obtained—very grateful to the eye—and many objects with low powers (1-inch and 2-inch) are brought out with a clearness and beauty that must be seen to be appreciated. Monochromatic light has been used with much success by many observers, and this prism is a very convenient mode of getting it.

With the eye-piece and prism in combination I can show *P. angulatum* and *quadratum* with splendid effect, magnified 1100 to 1500 diameters, and then by simply refixing the eye-piece (as in Fig. 190), and with the monochromatic light, I can show whole insects of small size with a 3-inch objective, the same illuminators serving thus two very widely different ends.

It will be seen that I invert the fixed lens as in the drawing to save using an inconvenient length of tubing. I think, however, the same purpose might perhaps be better answered by mounting the field-lens in a very short piece of tube as in Fig. 192 E, furnished with two screw heads, and running it up and down by means of two parallel slits in the tube C. In the same way a small diaphragm might perhaps be used with advantage between the two lenses of the eye-piece. I have not obtained any advantage by the *gradual* approximation of the two lenses of the Kelner eye-piece; they act best for each purpose (high or low power illumination) either close together in their normal position or a good distance apart. This arrangement of the prism cannot be used by daylight without giving monochromatic light; however it might be remedied by not cementing the piece of blue glass to the prism. In that case for night-work either a piece of deeper tint would have to be substituted when the monochromatic light was required, or two pieces of the same pale tint must be used."

Fig. 192.



Difference in the Appreciation of the apparent Size of Microscopical Images by different Observers.*—M. C. Montigny has undertaken an investigation of this subject with the object more especially of determining whether the differences which are well-known to exist in different persons, depend entirely upon the inequalities in the distances of distinct vision, objects, as is well known, appearing to be larger to short-sighted than to long-sighted persons.

In the first series of experiments the observers were not accustomed to microscopical observations, being nine pupils of the upper class of the Brussels Athénée, and the objects were discoid globules of human blood, which were compared with twelve small circles of different sizes, 0·5 mm. to 7 mm., traced on a card, and elliptical globules of frog's blood, compared with ten ellipses, the long axes of which increased from 1 mm. to 10 mm. The cards were placed at very nearly the distance of distinct vision of the particular observer, previously carefully ascertained. The same globule was always

* Bull. Acad. R. Sci. Belg., xlix. (1880) pp. 670–8.

observed, and care was taken that the eye of the observer was in all cases close to the eye-piece, so that the apparent size of the image should not be affected by any variation in the distance of the eye from the eye-piece. The magnifying power of the Microscope (for the author's sight) was 312.

The following table gives the results obtained, the case of the shortest sight being taken as unity:—

Observers.	Distance of Distinct Vision.		Size of the image of Human Blood-corpuscles.		Size of the image of Frog's Blood-corpuscles.	
	Absolute.	Relative.	Absolute.	Relative.	Absolute.	Relative.
	mm.		mm.		mm.	
A.	160	1·00	3·0	1·00	8·5	1·00
B.	208	1·30	2·8	0·93	7·5	0·88
C.	233	1·45	3·0	1·00	9·0	1·04
D.	233	1·45	3·5	1·17	9·0	1·04
E.	235	1·46	3·5	1·17	9·0	1·04
F.	270	1·70	3·0	1·00	8·0	0·94
G.	310	1·94	3·5	1·17	9·0	1·04
H.	320	2·00	3·5	1·17	8·0	0·94
I.	340	2·12	4·0	1·33	9·0	1·12
Average	256	1·60	3·31	1·10	8·61	1·00

It will be seen that the apparent size of the images did not vary in regular accordance with the variation in the distance of distinct vision.

In the second series of experiments observers were selected who were well accustomed to scientific observations; M. Piré, Professor of Natural Science, and MM. Niesten and Fievez, of the Royal Observatory.

The following table gives the results, arranged according to the length of vision of the observers:—

Observers.	Distance of Distinct Vision.		Size of the image of Human Blood-corpuscles.		Size of the image of Frog's Blood-corpuscles.	
	Absolute.	Relative.	Absolute.	Relative.	Absolute.	Relative.
	mm.		mm.		mm.	
Montigny	195	1·00	2·0	1·00	6·0	1·00
Fievez ..	240	1·23	2·3	1·15	7·5	1·28
Niesten ..	280	1·43	2·7	1·35	8·0	1·34
Piré ..	350	1·79	4·0	2·00	14·0	2·43
Average	266	1·36	2·75	1·37	8·87	1·51

Here the apparent sizes of the images follow exactly the order of the lengths of distinct vision, and M. Montigny concludes therefore that the variations that are found to exist in the case of experienced observers depend primarily upon the inequalities in the observer's vision.

There are however other influences, as may be seen by the case of M. Piré, whose estimations were too great in the two cases, relatively to those of the other three observers. Moreover in his case the relative size of the two kinds of globules varied from 2·00 to 2·43, while with the other observers they were approximately the same, the forms and different dimensions of the two corpuscles being without practical influence. If we take the mean of the relative sizes of the images of the two kinds of corpuscles for each observer, and divide by each of the means, and so find the length of distinct vision, the quotient ought to be approximately equal to unity for all four observers, if the apparent size of the images were exactly proportional to the distances of distinct vision. The following comparison shows however that it is not so:—

	M.	F.	N.	P.
Relative vision	1·00	1·23	1·43	1·79
Mean of the relative sizes of the images	1·00	1·20	1·34	2·22
	1·00	1·025	1·067	0·806

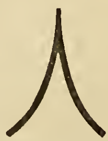
Whilst, therefore, the apparent size of a microscopical image is principally affected by the length of distinct vision, yet there is an additional influence, similar to the personal equation (*erreur personnelle*) of astronomers, which produces more or less modification.

Conditions of Aplanatism for Wide-angled Pencils.—It is a very common supposition that the necessity for constructing microscopical objectives of several lenses, instead of one only, is entirely a question of correcting spherical and chromatic aberrations,—that the practical method for correcting spherical aberration with a wide-angled pencil in fact consists in the *distribution* of the refraction over several lenses.

The dioptrical researches of Professor Abbe—from which the law of aplanatic convergence * was one particular result—show that the *successive* refraction of the rays by *several* lenses one above the other is the essential condition on which depends the *formation of an image by wide-angled pencils*, quite independently of the question of spherical and chromatic correction.

If an objective of say 140° angular aperture were constructed which should collect the rays in a similar mode to that of a single lens (where the semi-diameter of the emergent pencil $\rho = f \tan u$ and not $f \sin u$), and this objective was *perfectly corrected for spherical aberration*, a *plane* object would nevertheless be delineated like Fig. 193—a conical surface with a point, instead of a plane or moderately curved field.

Fig. 193.



A single lens can never fulfil the condition of aplanatism—that is of correct formation of the image—except for small angles for which the tangent and sine are nearly identical.†

Penetrating Power of Objectives.—We have added to the Numerical Aperture Table on the wrapper of the Journal a further

* See this Journal, *ante*, p. 322.
† See further on this subject, this Journal, iii. (1880) p. 509.

column (calculated by Mr. Stephenson) showing the "penetrating power" of objectives from a numerical aperture of ·50 to 1·52.

"Penetrating power" or "focal depth" is in inverse ratio to the numerical aperture. Thus, if a dry objective of 180° angle, or 1·00 N. A., is taken as unity, the penetrating power of one of ·50 N. A. would be 2, and of an oil-immersion of 1·50 N. A., ·667.

This follows from the consideration that the depth of focus (ϕ) is —other circumstances being equal—inversely proportional to the linear diameter of the delineating pencils at their emergence from the eye-piece. This diameter is $= 2 f a$, f being the focal length of the whole Microscope,* and a the numerical aperture, and the depth of focus is therefore inversely as a, provided the whole aperture of the system is utilized by the image-forming pencils.

It must be carefully borne in mind, however, that this column of "penetrating power" is by no means on a level, in practical value, with those indicating the "illuminating power" and "resolving power."

As was shown by Prof. Abbe in the paper translated at p. 680, the total *depth of vision* of the Microscope depends upon two factors: (1) the power of *accommodation* of the eye, and (2) the *depth of focus* of the objective.

The depth of focus again consists of several elements, the medium in which the object is, the magnifying power of the Microscope, &c. The *penetrating power* of the objective $\left(\frac{1}{a}\right)$ is *one* only of those elements, so that with exactly the same values of a (i. e. with the same numerical aperture) the depth of focus might considerably vary, if in the one case the object were in air and in the other in balsam, or if the amplification was different in the two cases.

By referring to the equation at p. 689,

$$\textit{Depth of vision} = n \frac{L^2}{N^2} \lambda + n \frac{L}{N} \frac{\omega}{a},$$

it will be better seen how many *other* elements make up the total effect of depth of vision, in addition to $\frac{1}{a}$, viz.:—

n = the refractive index of the medium in which the object is.
L = the distance of the virtual image from the "eye-point" above the eye-piece.
N = the linear amplification of the virtual image.
λ = the range of accommodation of the observer's eye in ordinary vision.
ω = the angle under which the circles of indistinctness may appear in the virtual image.

* The focal length of the *whole Microscope* is the focal length of that infinitely thin lens, which would give the same amplification of an object if projected to the same distance. If the amplification of the whole Microscope is = N, the virtual image being projected at a distance of vision = L, we have $\frac{L}{N}$ = equivalent focal length of the Microscope.

Penetration.—We gave at pp. 322–3 of vol. ii. and pp. 886-7 of vol. iii. an account of the discussion which was started in America on this subject, the view on one side being that penetrating power does not depend upon the aperture, but is only residual spherical aberration—that "the amount of penetration increases with the amount of the spherical aberration in the objective which has been left uncorrected, and decreases in proportion as the corrections for spherical aberration approach perfection."

The notion that penetration arises from the defective construction of an objective by the optician is, we need hardly say, wholly untenable.

We have delayed reprinting the remainder of the discussion until after we could give the translation of Professor Abbe's paper on the subject (see pp. 680–9), which has placed the question of penetration on the scientific basis which it has so long needed. The view that it is impossible for an objective to possess at the same time penetrating power and perfect definition is seen to be equally untenable, the defining power of an objective not being connected with its penetrating power, both low- and high-power, narrow-angled and wide-angled objectives, if properly made, all being capable of possessing the most perfect defining power.

The following is a summary of the remainder of the discussion to which we have referred, and is in reply to that printed at p. 866 of vol. iii.:—

Mr. C. M. Vorce* defines penetration in objectives as that quality by which the objective is able to present the images of different planes of an object in such close superposition, that the eye distinguishes them simultaneously, as the images of objects seen by the unaided eye are perceived; and he claims that the images presented to the eye by objectives having this quality of penetration impress the mind at the instant of view with a true idea of the bulk and substance of the object, and the arrangement and relation to each other of its parts. The reverse of this is true of the images presented by objectives, in which the above described quality has been sacrificed to the attainment of superior definition, and which he calls "defining objectives," as distinguished from the others called "penetrating objectives." Comparing the effect of these two qualities, the author argues that the mind is more likely to obtain a correct idea of the structure of an unknown object, if the images of it presented to the eye by an objective, resemble in character those received by the eye direct from natural objects, as is the case with penetrating objectives, than if the mind is compelled to successively compare with each other the images of separate parts and different planes, and laboriously trace out their relation to each other. He further contends that penetration is equally as necessary in high-power objectives as in low-power ones. The statement of the Rev. Mr. Dallinger, as to the $\frac{1}{35}$-inch objective made for him by Powell and Lealand, and which he used in his researches upon septic organisms, pub-

* Amer. Mon. Micr. Journ., i. (1880) pp. 170–1.

lished in August 1878, support, the author contends, the position taken by himself. Mr. Dallinger's description of the penetrating power and fine definition of the lens, is evidence that a superior objective for delicate original work, requires penetration as well as definition.

The practical conclusion is, that neither penetrating objectives nor defining objectives are alone sufficient for all classes of microscopical investigation; but both kinds are needed, of all the powers, and if the microscopist is limited in the number of his lenses, he will find the widest capabilities in the low-power defining, and high-power penetrating, objectives. The paper closes with the recommendation that opticians should endeavour to secure the best possible combination of defining power, with penetration, in the same objective.

Mr. Vorce further writes on the same subject:*—

"I partly agree with Dr. Blackham and his followers, but my views may be stated thus: Penetration is antagonistic to *perfect* definition, and, therefore, penetration is an objectionable quality in objectives whose purpose is definition solely. But mere definition is not the sole purpose of objectives, and in those objectives whose purpose is comprehensive view, penetration is a virtue as well as is flatness of field. Fortunately penetration cannot be got rid of by the opticians, except at the expense of the field of view; and Dr. Blackham's 1-inch objective still retains some of it, while it has gained much over the narrow angles in definition, and in this respect his objective approaches somewhat to the capabilities of that wonderful optical instrument, the human eye, which has *both* penetration and definition in a very great degree, in consequence of its inimitable 'compensating adjustment,' so well described by the Doctor. In some objectives this faculty of penetration is very striking. I remember distinctly with what surprise I saw, long ago, under a 1-inch of first-class English make, a stained specimen of *Utricularia*. At one view were seen the top layer of cells, the spiral vessel occupying the middle of the stem, and the bottom layer of cells; and all these with so much distinctness that, while the threads of the spiral vessel were in actual focus, the cells above and below were so nearly in focus that there was no dimness to their outline, and without changing the focus the size, shape, depth, and arrangement of the cells of the stem could be clearly seen, and the structure and central position of the spiral vessel perfectly seen. I am not ashamed to say that to this day I long to possess that objective, which, according to Dr. Blackham, is so faulty."

Mr. Vorce also takes exception to the figures of wire netting which we referred to at p. 887, contending that they are fallacious as shown on paper. As given, the figures "show exactly what a non-penetrating objective would show, viz.: all the lines equally defined; but with a penetrating objective one set of lines would be a little clearer than the other, and although there would be a *slightly* poorer definition of the lines in focus, there would be sufficient definition of both

* Amer. Journ. Micr., v. (1880) pp. 183–4.

sets, and no difficulty in seeing what was the relative position of the two layers. Having first ascertained the relation of structure, *then* comes the opportunity for the perfect, non-penetrating, surface-defining objective to get in its best work."

Advantage of the Binocular.*—Professor Abbe remarks :—

"The scientific value of stereoscopic observation will always remain a matter of individual opinion. The skilled microscopist who has become accustomed by years of practice to the solid interpretation of superficial images, forms an idea with complete certainty at one glance, or at most after a few turns of the adjusting screw, of the *solid* structure of even very complicated objects. Such an observer will only exceptionally desire any direct advantage from stereoscopic observation, as, for instance, when viewing objects of unusual composition; and what has been said above (see *ante*, p. 687) shows that no stereoscopic apparatus will ever make superfluous the acquisition of the art of indirectly recognizing solid forms.

"On the other hand, there is an advantage to be gained from *binocular* vision, as such, which is quite independent of its *stereoscopic* effect, and is in fact of importance precisely to those observers who have least to expect from the latter. I have been told by many competent microscopists in England that they use their binoculars whenever it is practicable, but not for the stereoscopic effect, but rather in order to employ both eyes, and avoid the evil effects which the continual strain upon one eye in course of time occasions. I have also found from my own experience that it would be well if regard were paid to this. It can scarcely be doubted that continuous one-sided vision by those who use the Microscope incessantly must gradually diminish the ability to use the eyes for ordinary vision—for example, in preparing objects and other work. From this point of view a binocular arrangement may be of value to those for whom stereoscopic observation is of subordinate interest."

β. Collecting, Mounting and Examining Objects, &c.

Apparatus for Pond-life.†—Mr. R. T. Andrews describes an apparatus for obtaining Entomostraca, &c., to obviate the cumbrousness of the strained hand-net, off which it is difficult to get the animals into a bottle readily. It does not require that one should put the net over the bottle, and dash the water up, and so draw off the animals, nor is a separate vessel required in which to immerse the net.

It consists of a tin tube $1\frac{3}{4}$ inches diameter, and $2\frac{1}{2}$ inches long, with its front end turned over for strength and tinned; the other end tapered in $\frac{5}{8}$ inch long to the size of the cork of the bottle, 2 oz. or 3 oz., employed, and a short length of about $\frac{1}{2}$ inch of tin tube soldered thereon to fit the cork, thus making the whole apparatus about $3\frac{1}{2}$ inches long. In the inside, rather more than half-way down the large tube, a ring of strong wire is soldered and tinned; a brass gas nipple is inserted from the outside, and a ring of tin $\frac{3}{8}$ inch in width is made to fit rather

* Zeitschr. f. Mikr., ii. (1880) p. 20. † 'Science-Gossip,' No. 199, p. 164.

tightly. On the mouth of the tube is placed a small piece of fine net, and with the ring pressed into the tube equally all round, and all projecting parts of the net above the ring cut off.

Having inserted the net, the apparatus, with both ends open, is waved through the water, which entering by the larger end escapes by the smaller, leaving the crustacea on the surface of the net. The cork of the bottle is then inserted in the smaller end, and some water taken up from the pond, which will then by its reverse action wash off the animals into the bottle. The use of the cork of the bottle obviates the necessity of a spare cork, which is apt to get lost. Care should be taken not to fish too quickly, or comparatively little may be got, as the large quantity of water cannot get through the net; and also to fill the apparatus with water slowly and not up to the brim, or what has been caught is washed out.

Hanaman's Collecting-bottle.*—This consists, as shown in Fig. 194, of an ordinary wide-mouth bottle or fruit-jar, having a number of holes half an inch or more in diameter bored through the side at a distance from the bottom corresponding to the capacity of the bottles in which the collector intends to bring home his material. Over the holes and around the bottle is tightly tied, or laced, a piece of fine muslin, which should be at least three times as wide as the holes in the bottle. Over the muslin, both above and below the holes, a rubber is placed so as to make all water-tight, except at the points corresponding to the holes.

Fig. 194.

Any quantity of water may be poured into the bottle, and it will rapidly run out through the muslin covering the holes, leaving the organisms which it contained in the bottle, together with only so much water as the lower part of the bottle, below the holes, will hold. This can then be poured into smaller bottles for transportation, by so inclining the collecting-bottle as to allow its contents to run out on the unperforated side. More straining surface can thus be gained, and the nuisance of funnels (necessary in the Wright's form) be dispensed with.

The principle upon which this bottle is constructed is subject to a variety of modifications. For instance, a slit of any width, from $\frac{1}{2}$ to 1 inch, may be filed in the side of a fruit-jar, and thus additional straining surface be gained; or a tin or zinc can may be used, having a broad slit in its side over which the muslin can be stretched.

If it be preferred to have the strainer inside the vessel, this can be easily arranged by using a vessel with a slit, and placing a diaphragm of thin iron (ferrotype plate) inside, somewhat wider and longer than the slit in the vessel, and having in its centre a slit of the same size as that in the vessel used. A piece of muslin can be drawn over the

* Amer. Mon. Micr. Journ., ii. (1881) pp. 121–2 (2 figs.).

diaphragm, covering its side next the interior of the vessel and passing over the edges, thence upwards, downwards, and laterally through the slit in the vessel and around the outside of the same, as in the former case, rubber bands being applied as before over the upper and under edges of the muslin. There is no particular advantage to be gained by this mode of construction, but it is suggested as a modification which may be deemed desirable by some.

It is necessary that the holes in the vessel be bored at some distance from the top of the bottle, in order to get sufficient weight of water to force itself rapidly through the strainer. If the holes are made near the top of the vessel, it will not work much more rapidly than the Wright's form, although even in that case the absence of funnels is a great convenience.

Cleaning Diatoms.*—Mr. K. M. Cunningham gives some additional hints as to the application of bisulphate of potassa in cleaning diatoms which is applicable to the treatment of nearly all varieties of diatomaceous material:—

"Proceed as follows.

Crush to powder a few crystals of the bisulphate of potassa, and add to it a proportionate quantity of the material to be cleaned, mix intimately together, and transfer it to a hollow space practised in the end of a sound piece of charcoal. Then with the blowpipe direct the flame of a candle upon the mixture, when a violent boiling up will ensue, and when it finally ceases to fuse readily, when the potash appears opaque and of a whitish colour, it is to be removed and dropped into a thimbleful of water, and boiled a few seconds; the potash dissolves readily, and liberates the sand and diatoms in a cleaned state. After settling in a shallow porcelain saucer, draw off all the water and collect the diatoms into the smallest compass possible, and transfer them to a nickel; take the nickel in the wire tongs, and dry with blowpipe flame; it will dry immediately, and the diatom powder is to be scraped off and put aside for use.

All the requisites for the above process consist of a common dime blowpipe, small wire tongs, 6 inches long, to hold the thimble, nickel, &c., a pocket coin, a brass thimble, a few pieces of sound charcoal, a candle, and a small supply of the bisulphate of potassa.

When the bisulphate cannot be readily procured, an admirable substitute may be found in the following, viz. common powdered sulphate of potash, and a small quantity of sulphuric acid, both of which are always found in prescription drug-stores. In using these materials, the diatoms to be cleaned are mixed with an equal quantity of the powdered sulphate of potassa, and a few drops of sulphuric acid are mixed with it; it solidifies at once, and can be broken into suitable pieces to be fused on the charcoal, as before described. The superior advantages of the process here described will become apparent to those who have tried the acid methods of cleaning."

In a subsequent note † the same author says:—

"The following process is the result of a recent fortuitous

* Amer. Mon. Micr. Journ., ii. (1881) p. 93. † Ibid., p. 114.

experiment. Let us suppose that we have succeeded in bringing a quantity of diatomaceous material to the state of a beautiful white powder, as previously described, by the use of the bisulphate of potassa, or the more easily procured substitute suggested. We then proceed as follows: Procure a piece of silk about four inches square, of good quality, and of very close texture; moisten it thoroughly at first, and in its depressed centre place a small portion of the fused material to be cleaned; then add to it several drops of water to bring it in solution, collect the sides and corners of the silk together, twist them to prevent the escape of material or fluid, compress immediately above the material, and carry the pressure down gradually, without however bringing the pressure of the fingers to the bottom part of the silk; this compression forces out the water, and with the water a large percentage of the undesirable impurities contained in the material, while the close texture of the silk holds back the various diatoms and disks with the larger particles of sand. After the first compression a few more drops of water are added, and the pressure renewed as before. The silk is then turned inside out, and washed by gentle shaking in a deep watch-glass to remove the diatoms, &c. We now note an absence of milkiness in the product, and the cleaned residue remains at the bottom of the crystal; by transferring this to a deeper receptacle, we can then dip up the diatoms with a pipette to mount direct on slide or cover-glass. This method gives surprisingly fine results."

Colouring Bacteria.*—In a recent paper on this subject C. Weigert (classifying Bacteria into Cocci and Bacilli, and the former again into Micrococci and Megacocci) points out that two methods are available for colouring these microganisms:—1stly, in clear fluids, and in dried thin layers; a method first employed by Obermeyer for preserving bacteria in the case of *Spirillum* and *Spirochœte Obermeyeri;* Koch being the first to colour preparations dried in this way; 2ndly, by sectional preparations hardened by absolute alcohol.

For most micrococci the nucleus colouring substance employed by zoologists may be used; as, for example, Schweiger-Seidel's modification of carmine, aniline, or hæmatoxylin. Micrococci are coloured red by all nucleus colouring kinds of carmine, as purpurin, fuchsin, and magdala: brown by Bismarck-brown and vesuvian; brownish violet by carmine, with subsequent washing of the preparation with alcohol to which some ferric sesquichlorate has been added; green by methyl-green: blue and violet by hæmatoxylin, iodine-violet, methyl-violet, dahlia, and gentian-violet. All aniline colouring matters are used by super-colouring the sections in strong aqueous solutions, and then removing the colour either in acetic acid or in alcohol, or in both, until the nucleus is differentiated.

For the larger Bacilli only the nucleus colouring aniline colouring matters can be employed; carmine and hæmatoxylin are useless

* Arch. f. pathol. Anat. (Virchow), lxxxviii. (1881) pp. 275-315. See Bot. Centrabl., vi. (1881) p. 423.

The basic aniline colours to be specially recommended are Bismarck-brown, methyl-violet, methyl-green, saffranin, fuchsin, and magdala, and gentian-violet most of all, employed as a 1 per cent. aqueous solution. In this the section is laid, and soon becomes diffused with blue, and is then placed for an hour or more in alcohol, and finally in water, alcohol, or oil of cloves. The most important condition is that the section be well hardened. In preparations coloured by gentian-violet the nucleus can then be coloured red by carmine, Partsch's alum-cochineal, Grenacher's alum-carmine, borax-carmine, or picrocarmine.

The following method is given for the manufacture of picro-carmine as a micro-chemical reagent:—2 gr. of carmine are immersed in 4 gr. of ordinary ammonia, and placed for 24 hours in a spot protected from evaporation, and then shaken up with 200 gr. concentrated solution of picric acid. After allowing to stand again for 24 hours, everything soluble is dissolved. Very small quantities of acetic acid are then added, until the first slight precipitate appears; and after the lapse again of 24 hours, a few drops of ammonia are added.

Colouring of Suberized Membranes by Fuchsin.*—M. Olivier gives the following process for colouring suberized membranes:—the sections of the roots are treated with a solution of fuchsin, made with equal parts water and alcohol, by which the whole preparation is coloured. The sections are then steeped in absolute alcohol, which dissolves the fuchsin out of the membranes, which are composed of cellulose, whilst the suberized walls remain of a red colour.

Nigrosine for Colouring Nuclei of Vegetable Cells.†—M. Errera finds "nigrosine" an excellent reagent for the nuclei, which are coloured a very deep blue, and stand out very clearly, the rest of the cell remaining practically colourless.

Nigrosine is one of the derivatives of tar, and belongs to the class of indulines. It is soluble in water and insoluble in alcohol and ether, and for colouring should rank with safranine, methyl-green, and other recognized agents.

The preparation should be placed for a short time in a solution of nigrosine, and then washed in distilled water until the water takes up no more colouring matter. It can then be mounted in glycerine or in balsam or dammar. The former method is preferable if it is desired to study the protoplasm and the part of the nucleus formed by achromatine (of Flemming). The second should be adopted for the examination of chromatine (= nucleine), as the grains of starch which hinder observation are rendered invisible.

Staining Nuclei.‡—H. Grenacher uses for discovering the nuclei in organs which abound in pigment—viz. the eyes of spiders—a method which will probably be found useful in other cases, especially

* Bull. Soc. Bot. France, xxvii. (1880) pp. 234–5.
† Bull. Soc. Belg. Micr., vii. (1881) pp. cxxxiv.–v.
‡ Unters. u. d. Sehorgan d. Anthropoden, 1879, p. 24. Cf. Zool. Jahresber., i. (1880) p. 38.

when the treatment of the specimen with nitric acid is likely to render subsequent staining by the ordinary means difficult. The staining is effected by putting the colouring matters into the fluid itself, adding the slightest trace of nitric acid, and leaving the preparation to rest. Solution takes place, however, so slowly that it is from twelve to twenty-four hours before the clear space round the section appears. The pigment acts in this case like a staining material introduced from without; it disappears from those points where it previously existed, and is precipitated in the nuclei, the other parts of the tissue receiving only an insignificant amount.

Seiler's Imbedding Substance.*—Dr. C. Seiler says that after many experiments he has found pure paraffin two parts and rendered mutton tallow one part, to be more satisfactory than any other imbedding material in the majority of cases, because if poured into the well of the microtome at a temperature of about 120° it will not shrink away when cooling, either from the tissue or from the wall of the well.

Strasser's Method of Imbedding.†—H. Strasser adds from 3 to 4 parts of tallow to the imbedding mixture recommended by Kleinenberg (spermaceti 4 parts, castor-oil 1 part). In order to be able to arrange very small objects in the required position and conveniently for cutting sections, he places them between plates of mica in the warm mass, whose temperature must not exceed 45° C. After cooling, the laminæ of mica may be readily detached, and the mass containing the object in the required position, and forming a thin plate, can then be fastened to a block of less easily melted material by means of heated pins.

Loewe's Modification of the Ranvier Microtome.‡—Dr. L. Loewe describes this as follows:—"The microtomes hitherto devised are based upon two distinct principles. One of these is that of Verick and Rivet, since variously modified by Brand, Leiser, Weigert, Long, and others, leaving the general principle, however, unaltered. By this instrument the preparation is raised on an inclined plane, as its height is reduced by being cut away, the cutting knife always remaining at the same level (see Fig. 195).

"When the object is of small dimensions this instrument gives results of great practical utility, and is certainly to be preferred to free-hand cutting. But it is different when objects of large dimensions and complex character have to be cut, such as the head of a full-grown rabbit with skin and hair in a continuous series of frontal sections, and it cannot be employed in any of those cases where application of great force is required for dividing very hard parts, teeth, bones, &c. This defect is inherent in the principle of the apparatus, and cannot be obviated by any modification, however

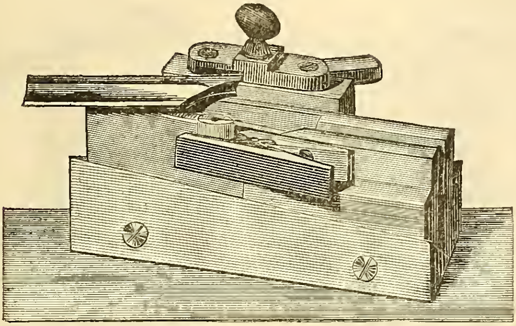
* 'Compendium of Microscopical Technology,' 1881, pp. 47–8.

† Morphol. Jahrb., v. (1879) p. 243. Cf. Zool. Jahresber., i. (1880) p. 35.

‡ 'Beiträge zur Anatomie und zur Entwicklungsgeschichte des Nervensystems der Säugethiere und des Menschen.' Cf. Zeitschr. f. Mikr. ii. (1880) pp. 123–39 (5 figs.).

ingenious, as will be evident from the following considerations. If we watch any one making fine sections of a complicated object with the free hand we see that at first the hand is held with the back inclined downwards, and in a position somewhat similar to that

Fig. 195.



assumed on going to shake hands. From this the hand is gradually changed during the cutting into a position inclined almost completely upwards, and at the same time, if the operator is not left-handed, the end of the knife describes an arc of 90° in the direction of a watch hand, the part of the knife which is furthest from the hand having the greatest rotation, whilst that where the knife is fastened to the handle remains almost stationary. This movement cannot, for mechanical reasons, be imitated in this microtome unless the guide of the knife and of the preparation (on the inclined plane) is changed from a straight line into one curved to the right, and at the same time a combined circular movement is given to the block which serves for fixing the knife, in which case a sickle-shaped knife fixed to the shaft at an obtuse angle must be used.

'The second or *Ranvier* principle appears to be more practical and capable of satisfying every requirement. Its origin is due to Ranvier, but it has since been considerably improved by Welker, Beetz, Gasser, Gudden, Schiefferdecker, and others. It is to this form that the author's modifications have been applied.

" As modified, it has the form represented in Fig. 196, and consists of two separable parts—(1) the microtome-cylinder proper, with its micrometer-screw for raising the preparation, and (2) a clamp which fastens the cylinder to the table (Fig. 197). The latter has a divided ring (seen in the upper left corner of the figure), which by a screw can be firmly attached to the neck of the cylinder. It is essential that the cylinder and the clamp should be capable of being detached, both for enabling the instrument to be cleaned, and also for altering the position with respect to the table of the object imbedded in the cylinder.

" The modification consists, therefore, in this: Instead of the microtome being held in the hand (Ranvier), or fixed in a water reservoir (Gudden), or standing free on the table (Schiefferdecker), it is attached to the table, and by this means both hands are set free. Compared with Gudden's microtome, there is a gain in the increased convenience and the reduced loss of light; while there is in-

Fig. 196.

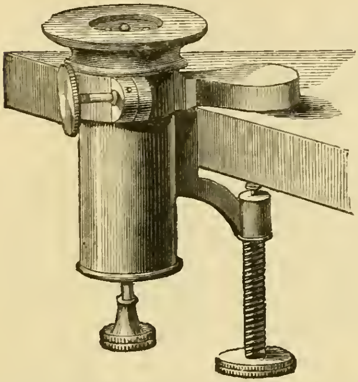
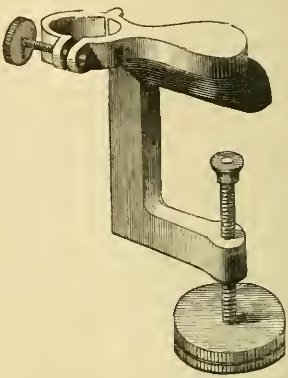


Fig. 197.



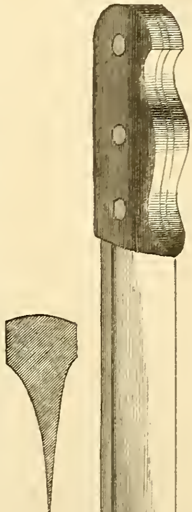
creased stability and firmness, compared with Schiefferdecker's method of simply placing the instrument on the table.

"It may be objected that cutting under water is impracticable with this instrument. To this it may be replied that section cutting under water is only intended to obviate the brittleness of the preparation; the same object is attained by glycerine jelly in a far more practical manner. This imparts to the whole a uniform consistency for cutting purposes, and binds it together into one firm mass without a trace of brittleness. Cutting under water can therefore be dispensed with.

"Katsch, of Munich, has made an arrangement for the larger instruments, by which a large wheel with four projecting teeth—placed horizontally and soldered to the lower head of the micrometer screw—allows the bottom of the cylinder to be raised or depressed more quickly. Rainer, of Vienna, has made the whole bottom of the cylinder, together with the micrometer screw, to fit in with a kind of bayonet fixing, so that a rapid change of the object (imbedded in oil and wax) is practicable. The fixing of the wax and oil cylinder enclosing the object is effected in the older instruments on Gudden's plan by means of three small buttons, the section of which is mushroom-shaped, which project from the movable base-plate of the microtome. Latterly Thamm, of Berlin, has substituted for these buttons a long groove, 1 cm. broad and 1 mm. deep, which runs across the middle of the base-plate of the cylinder; by this means facility in taking out the oil and wax cylinder is attained."

Knife for Large Sections.—Dr. Loewe also explains that for large sections through the bodies of mature animals a very long, heavy, and broad knife should be used, as in Fig. 198, which also gives a transverse section showing the peculiar grinding away of the blade to form a biconcave surface. Its total length is 64 cm. or deducting the two handles 44 cm., and its breadth 4·5 cm. The thickness of the back is 1·5 cm., and its weight 2062 grammes. The two solid fixed handles of lead are each 1 decim. long, and can be conveniently grasped with the whole hand. Lead is employed to increase the weight of the instrument.

FIG. 198.



The force with which the edge of the knife is applied to the object is obviously equal to the product of the weight of the knife and the velocity of its motion. It takes a very short time to learn how to manipulate a heavy knife with as much ease as a light one, and, in general, the heavier the knife the easier it is to cut with. For this reason, microtomes which are adapted for heavy knives are far preferable to those which, like the Rivet and its modifications, can only be worked with thin knives.

It has been urged against the principle of heavy knives that many animal objects are much too delicate for them, that by such large cutting instruments friable preparations can indeed be crushed, but not cut. This is not so. It is simply necessary to harden the preparation properly (which can be effected perfectly by the method described in the preceding note), and any object, however delicate or brittle, will not be affected by the weight of the knife. There can certainly be nothing more difficult to cut than the ova of *Rana* or *Bufo*, and yet, when these are properly hardened and well permeated with Klebs' substance, they can be beautifully cut with the largest knife. Sections of embryos of rabbits, 3 mm. long, are also cut, notwithstanding such objects are most delicate.

Making Sections very quickly.*—H. de Lacaze-Duthiers recommends, for obtaining sections very quickly for preliminary investigation, that the object should be put into a strong, dark yellow, very hot solution of chromic acid. In a few minutes it will be so far hardened that the spot which is to be cut can be isolated; the latter (e. g. a small ganglion, &c.) is then transferred to a weak light yellow chromic acid solution of the ordinary temperature, and there left until any other preparations which may have to be made from the animal are completed.

As imbedding material, glue is used, which must be of the best quality, i. e. quite transparent; it is used as prepared in two different

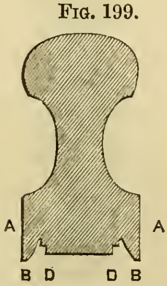
* Arch. Zool. expér. et gén, vi. p. xxxviii. See Zool. Jahresber., i. (1880) p. 35.

ways, as thin sheets and as a solution of the consistence of syrup; both must be kept in a damp atmosphere (under a glass shade, in case the air by the sea does not contain enough moisture); the sheets then remain soft, and have the proper consistence for cutting. The piece to be imbedded is now fastened to a sheet, near to its edge, by a drop of the liquid; a piece of tissue-paper or gelatin paper is saturated and softened with the solution and laid upon it, and on this notes as to direction of cutting, &c., can be written; other objects are laid on the same sheet parallel to the first. Finally, the whole is covered with a second and thinner sheet of glue, which quickly unites with the first. The mass thus formed remains so transparent that the prepared objects and notes are easily seen. The part of the sheet which contains the objects is now again covered by the bell-glass; the exposed part dries rapidly and becomes harder. It is soon possible to cut sections; the direction of cutting may be easily controlled with the aid of a lens, owing to the transparency. The sections are placed in water, and the glue dissolving readily, they are then fit for examination. The only difficulty is to keep the glue soft enough; if it becomes too hard, it is impossible to make sections; slight moistening is of use in this case; if the pieces of tissue are squeezed up by the drying of the glue, it is remedied by the swelling which is caused by this moistening.

Cutting Sections of Myxomycetes, &c.*—For the lower vegetable forms with naked protoplasm, osmic acid is recommended. The currents in the protoplasm of Myxomycetes are instantly suspended, and in a very short time the plasmodium is sufficiently hardened to enable sections to be cut.

Dayton's Cell.†—Fig. 199 represents a perpendicular sectional view through the centre of a metallic die or punch. The sides A A, however, should be bevelled to form a cutting edge at B B. By prolonging the sides and forming another cutting edge at D D, rings for transparent cells may be made, the raised edge forming an efficient protection to the cover-glass.

Fig. 199.



The process of making the cell is thus described by Dr. R. Dayton:—

Drop melted sealing-wax or shellac upon a slightly warmed and oiled surface of plate-glass, until material has accumulated sufficient to a little more than fill the die, press the die down quickly and forcibly, and as the surplus resin exudes revolve the die so as to cut through to the glass. The cell produced by this process will be polished more or less in proportion to the finish the die has received in its manufacture.

The advantages of this cell are, that it is easily and quickly made, and can be modified as to form at slight expense. It can be attached

* North. Microscopist, i. (1881) p. 201.
† Amer. Journ. Micr., vi. (1881) p. 117 (1 fig.).

to the slide and the covers to the cell, by means of heat alone, or by varnish. A thin or thick object can be mounted in the same cell by placing the cover either upon the shoulder or upon the rim of the cell, and last, and not least, to those who have large exchange lists, is their inexpensiveness, as they can be made for less than two cents per dozen.

Fluid for Mounting Infusoria, Algæ, &c.*—Dr. T. F. Allan uses the following solution for mounting Infusoria, Algæ, Characeæ, &c., which it is said preserves the arrangement of the cell-contents in a most excellent condition.

Wood-vinegar, sp. gr. 1·04, 100 parts.
Salicylic acid, 1 part.

Shake and allow to settle. This mixture is named "salicylic vinegar."

For Algæ, mix salicylic vinegar 1 part, glycerin 1 part, water 20 parts.

For Infusoria, mix salicylic vinegar 1 part, glycerin 10 parts, water 40 parts.

Preservative Fluids for Botanical Preparations.† — In 1872 MM. J. Groenland, M. Cornu, and G. Rivet published a little work ‡ on the preparation of Botanical objects for the Microscope, in which they gave a series of formulæ which they had found useful. This work being now rare, M. G. Huberson has reproduced these formulæ as follows:—

No. 1. *Equal volumes of glycerin (as pure as possible), alcohol, and camphor-water.* This fluid will preserve, either in bottles or cells, the greater number of vegetable tissues, and especially all cellular tissues of a certain solidity, such as horny albumen, epidermis, sections of leaves, and all woody, fibrous, and vascular tissues. Certain preparations it renders too transparent, especially those of very young organs; a fault that is corrected by the addition of water. (For tissues with cystoliths Nos. 3, 4, and 5 are preferable.)

No. 2. *Three volumes of glycerin to two of camphor-water* may be put to the same use as No. 1, but only in closed cells.

No. 3. 100 *grammes of distilled water to two of chloroform.* Shake up together for five minutes at least. About 1 gramme of the chloroform is dissolved, the remainder is precipitated at the bottom, and serves to keep the fluid saturated. It is used for all tissues in course of development and still tender, prothallia, embryonal sacs, archegonia and the fecundating organs of cryptogams in course of formation. (For the same parts completely developed Nos. 1 and 2 are preferable.)

No. 4. *The same as No.* 3, *with the addition of* 4 *or* 5 *grammes of*

* Amer. Mon. Micr. Journ. ii. (1881) p. 98.
† Brebissonia, iii. (1881) pp. 104–8.
‡ Des préparations microscopiques tirées du règne végétal et des différents procédés à employer pour en assurer la conservation. (8vo, Paris, 1872.) 76 pp. and figs.

glacial acetic acid. This preparation preserves Confervæ perfectly without contracting the chlorophyll, to which it merely gives a brownish tint. It presents one peculiar advantage in that it absorbs the air-bubbles which objects often contain after being placed in the cell. In this manner pith and fungi with numerous spores (Agarics, *Penicillium*) which often retain, do what one may, a large number of air-bubbles, can be prepared with success and without the necessity of taking numerous precautions. A few days after the cell has been closed, the air-bubbles, if not too numerous, will have disappeared. Consequently, whenever washing in alcohol is inconvenient, this fluid should be used.

The acetic acid destroys the calcareous concretions which sometimes exist on the surface and even the interior of Algæ. Bubbles of carbonic acid are in this case given off, and for some days spoil the appearance of the preparation, but they disappear before long. The proportion of acid is pretty strong, but experience shows that a slight excess of this acid is not injurious.

No. 5. *Camphor is dissolved in chloroform until it is saturated.* The superfluous camphor is as far as possible removed and fresh chloroform equal in amount to the first is added. Four grammes of this solution is dissolved in a litre of distilled water; no precipitate being produced.

This fluid may in most cases replace No. 1. It gives less transparency to the preparations, but it possesses the advantage of but slightly contracting the primordial utricle. For this reason it may be employed for preserving even the most delicate marine and freshwater algæ, desmids, diatoms, with their endochrome, &c. For the very delicate algæ, such as the Confervæ (*Spirogyra*, *Rhynchonema*, &c.) preference is given to the following:—

No. 6. 75 *grammes of camphor-water*, 75 *of distilled water, and* 1 *of glacial acetic acid.* This formula was invented by Dr. Ripart and cannot be too strongly recommended.

No. 7 *is a gummy mixture* for fixing the objects in the cells before putting in the preservative fluid. Dissolve, cold, completely white gum arabic in twice its weight of camphor-water, adding to the solution, which is not perfect till the expiration of two or three days, three-quarters of its weight of glycerin. It should be kept several months in a long narrow bottle till the fluid has become completely limpid through the deposit of the corpuscles which it at first holds in suspension.

No. 8 *is a gelatinous mixture* intended to replace Canada balsam. Soak perfectly white gelatin in cold water for about twelve hours, drain it, and set the vessel which contains it in warm water. When it is melted mix an equal volume of glycerin with it. The mixture solidifies on cooling. When required for use it is liquefied by plunging the vessel containing it in warm water.

No. 9. 500 *grammes of distilled water and* 1 *of phenate of soda.* This fluid will preserve (in cells only) a host of vegetable tissues and microscopical plants. The previous formulæ are in general preferable, but in cases where they do not answer this fluid may be tried, especially for objects which are very delicate and very sensitive to the effects of endosmosis.

Chloral Hydrate for Preserving Tissues.*—Dr. W. W. Munson, being often obliged to postpone the dissection or other preparation of insects, &c., finds that putting a little chloral hydrate into the water preserves all animal tissues perfectly, without hardening or otherwise changing them, for any length of time. Five grains to an ounce of water is strong enough for all small objects.

Vegetable specimens may be kept fresh in the same way. The solution must not be too strong, say only a grain or two to the ounce.

Chalon's Microscopic Finger.†—Under the title of "Arrangement des Diatomées pures," J. Chalon describes an apparatus for picking up diatoms out of a mixed gathering, which, as he rightly says, "in default of any other merit possesses at least that of simplicity."

To a thin piece of deal 15–20 cm. long a hog's bristle of 4–5 mm. is articulated by means of a spherule of lead (a large shot) held between two brass rings. It forms, therefore, a lever with unequal arms, the wood one part and the bristle the other. The spherule is the fulcrum.

Any movement given to the extremity of the long arm of the lever becomes very slight and also reversed at the end of the bristle, so that in working with a power of 50 to 60 diameters the bristle seems, under the objective, to have a direct motion and an ordinary speed. It might be easily supposed that a needle was being used with a simple lens.

The apparatus is fixed to the stage by a clamp. If it is attached to the fixed part of a mechanical stage, great facility would be given for bringing any desired object under the point of the bristle. With a little experience 30 to 40 diatoms can be arranged in an hour.

Mounting Opaque Objects.‡—Professor A. H. Chester, in a paper on this subject, says:—

"In mounting opaque objects the chief difficulties to be overcome are in fixing the object to the slide, and in preventing the cement from running into the cell after mounting. After many trials I have adopted the following method. The objects, if light, are attached by means of a thin solution of gelatin. A little spot of the solution is dried on the slip, and the objects are then placed upon it and attached by breathing on the slide. This is then allowed to remain on the hot plate until all moisture has been driven out. If a heavier object is to be mounted, a circle of Brunswick black is turned on the centre of the slip, which is then placed on the hot plate until so hard that the object will not sink into it. It is allowed to cool, the object placed in position and fixed by heating for a moment over the lamp. If just the

* Amer. Journ. Micr., vi. (1881) pp. 117–18.
† Bull. Soc. Belg. Micr., vii. (1881) pp. cxx.–i.
‡ Amer. Journ. Micr., vi. (1881) p. 125.

right amount of heat has been applied, the object will be firmly attached, but will not sink into the cement. The slide is then placed on the hot plate, where it remains until the japan is baked perfectly hard, so that no subsequent heating will soften it.

After the objects are fixed and sufficiently heated, they are allowed to cool, and the ring applied to make the cell. This ring is of tin-foil, made as previously described.* A ring of black cement is carefully applied to the cool slide, and the tin ring pressed into it. Care is taken that none of the cement comes into the cell. This cement is a quick-drying dead colour, used by coach painters, and I think will soon be put on the market in tubes for use in mounting. It is thick, and sets in a few minutes. If necessary, another tin ring is laid on top of the first, in the same cement, and the cell is in this way built up until the cover-glass will be close to the object but not touching it. The cover is then put on with the black cement, clipped and set away. In an hour the clip can come off and another coat of black may be applied. This must dry hard, which requires several hours, when another coat is put on and left to harden. The next day a coat of shellac cement is put on. This should not be too thick, and the mount should be examined carefully to see that no holes are left in the shellac. The next day the white zinc may go on to fill up the angles and make a smooth surface, and in two or three days the final finish may be applied. It will thus be seen that the slide is completely finished in four or five days from the time it is started, that there is no need of having a lot of cells made in advance, but that each one is made to suit the particular object it is to contain, and if proper care be taken the object will be firmly attached to the slide, and there will be no running in. Of course some experience is required to know just when the conditions are fulfilled to ensure complete success, but it may be attained in the use of the means I have just pointed out.

For fluid mounts in cells I use the tin rings, cementing them to the glass with shellac, which I generally thicken with Chinese vermilion. After the object and fluid are put in the cell, the cover is laid on, the excess of liquid pressed out carefully, and the whole dried with blotting paper. Some of the thickened shellac is then put around the edge of the cover and left to harden. In an hour the slide can go on the turn-table, and a ring of shellac may be applied. No clip should be used. The next day the slide may be carefully washed and dried, when it is ready for another shellac ring. After this is set the white zinc may be put on as usual. Of course the fluids used must not be those that dissolve shellac, but camphor water or glycerin may be used without fear."

Preparing Cuticles of Plants.†—Mr. F. Kitton gives the following process for preparing slides of the cuticles of *Deutzia*, *Onosma*, *Alyssum*, *Hippophaë*, *Equisetum*, scalariform and spiral vessels, &c. The apparatus required is only a small porcelain saucer holding about an ounce, a spirit-lamp, a large watch-glass, two or three mounted bristles (rabbit or cat's whisker), about $\frac{3}{4}$ inch beyond the

* See this Journal, *ante*, p. 702.

† Sci.-Gossip, 1881, p. 182.

handle, and a human hair mounted so as to form a small loop. Also a "lifter" made of a "thick" thin glass cover, about $\frac{3}{4}$ inch diameter (this is more convenient if three of its sides are squared), cemented to a piece of glass tube $\frac{1}{4}$ inch diameter, and $\frac{1}{8}$ inch bore, by filling about $\frac{1}{4}$ inch with broken shellac, to be carefully melted, and then placed on the square edge of the cover, which should be hot. Chemicals: nitric acid and chlorate of potash, and distilled water.

The *modus operandi* is as follows: select, say a medium-sized *Deutzia* leaf, cut out a square, or any other shape, but take care to leave none of the margin, half fill the saucer with equal parts of nitric acid and water, and to this add a small pinch of the chlorate of potash, and gently boil over the lamp; carefully watch the leaf, and when the upper and lower cuticles begin to separate remove them by means of the lifter into a watch-glass filled with distilled water; the two cuticles will sometimes separate of themselves, but much more frequently require a little manipulation with the bristle to separate them: this may be done by carefully inserting it between them. When separated, float the lower cuticle * on a thin cover, and with the hair loop gently scrape off any remains of fibre, &c. The upper cuticle may be cleaned whilst floating by scraping the under surface with the loop; when clean float on to a glass slip. It is usually very difficult to turn the cuticle over, and as it is always desirable to have the external surface uppermost, it is necessary to mount one on the cover and one on the slide. A more difficult but better plan is to leave one of the margins of the leaf intact, and when clean float both cuticles on to the slide; when dry place the cover or the slide in turpentine, and mount in Canada balsam. The siliceous cuticles of *Equisetum* stems, barley-straw, cane, rice-husks, may all be obtained by this process, but they will not bear drying; they must, therefore, be removed first to strong methylated spirit, and then ether, and lastly turpentine.

Mounting Raphides.†—Mr. S. A. Webb gives the following process for obtaining and mounting raphides:—

"The hanging plant known as 'Wandering Jew' (*Tradescantia*) contains myriads of these needles. Place a slide upon the turn-table, cut off the stem of the plant transversely (somewhat obliquely), and you will find the juice forming a half drop on the cut end. Set the table in motion without delay, and place the drop on the cut end upon the centre of the slide, slowly moving it outward as the table turns, so that it shall not twice pass over the same spot, until you have formed a scroll-like circle with the juice of about $\frac{1}{4}$ inch diameter. Let the slide remain fifteen or twenty minutes, place a drop of fresh balsam upon the centre, and place upon it a half-inch cover-glass. Let the cover sink down slowly until it is in contact with the balsam throughout. If not level, press it gently, so that the balsam shall fill out handsomely. Set it away, but do not heat it. It will require some time to harden, but if in haste to use it, as soon as the balsam

* By upper and lower cuticle is meant that which may be upwards or downwards in the saucer.

† Amer. Mon. Micr. Journ., ii. (1881) p. 71.

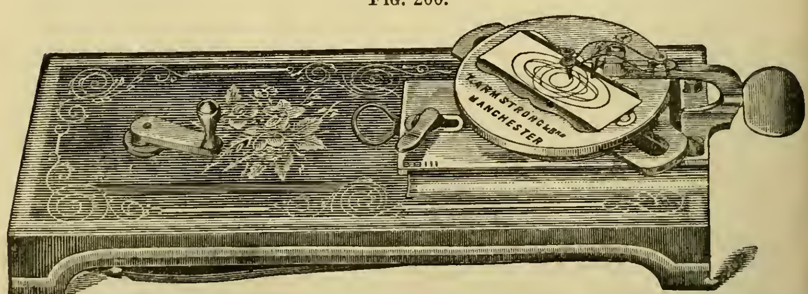
at the edge of the cover has hardened somewhat, run a circle of a solution of shellac in alcohol, so as to touch both the edge of the cover and the slide. This will hold all fast, even though the balsam be still liquid within. Finish this if you choose at once with tube paints, and your slide is done. Examine the slide by oblique (black-ground) light, or far better, if you have it, by polarized light. Use the green, not the purplish coloured 'Wandering Jew.' You will find the needles beautifully distributed, clean and looking like polished steel."

Preparing Crystals of Metals.*—Professor A. H. Chester gives the following as his method of procuring crystals of the various metals:—

"The beautiful and rare crystals of gold of hexagonal form are prepared by first dissolving the gold in ten or twelve parts of mercury, and boiling for several hours. The mercury is then dissolved out by means of nitric acid, and the crystals of gold left of hexagonal shape, their beauty depending upon the perfection of the process. The silver, tin, copper, and other metallic crystals are best obtained by precipitation of the crystals by means of the battery. To obtain tin crystals the simplest method is to immerse the end of a bar of tin in a strong solution of the chloride. A thin layer of water is poured on the top. In a few days the crystals of tin will be found attached to the bar in the layer of water."

Blue Glass for Test Objects.†—E. Mauler mounts diatoms intended as difficult tests on or under blue glass. The object is twofold:—1st, to render the image clearer by monochromatizing the light entering the objective. In this case it is the cover-glass only which is blue, and it "has the effect of improving the often confused resolutions given by objectives whose chromatic aberration is badly corrected." 2nd, by using blue glass for the slide, or for the bottom of the cells, the light reaches the object monochromatised, a plan which replaces the more inconvenient one with sulphate of copper. Stronger illumination is of course necessary than with ordinary glass.

FIG. 200.



Armstrong's Universal Turntable.—This instrument (Fig. 200) is made by Messrs. T. Armstrong and Brother, of Manchester, and

* Amer. Journ. Micr., vi. (1881) p. 125.

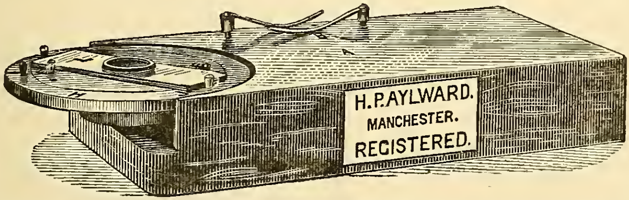
† Journ. de Microgr., v. (1881) pp. 111-12, and Bull. Soc. Belg. Micr., vii. (1881) pp. cxxxiii.-iv. and cxliii.

is claimed to be entirely different from any other form yet made.

It is constructed upon the principle of the "elliptical chuck," and so enables either circles or ovals to be traced with equal ease. It may also be used for cutting thin glass covers, either oval or circular, as well as for general mounting purposes.

Aylward's "Concentric" Turn-table.—This self-centering turn-table, designed by Mr. H. P. Aylward, of Manchester, is shown in Fig. 201. It is claimed to be accurately self-centering, and still

Fig. 201.



simple in its construction, so as not to be liable to get out of order, and at the same time easy and rapid in use. It essentially consists of two plates, the inner revolving on a pivot, whilst the outer one revolves concentrically on the inner, some pins being so arranged that by a simple turn of the outer ring they firmly grasp the slide and centre it, a simple reverse movement instantly liberating it. It will answer for slides of various widths, from 1 inch to $2\frac{1}{2}$ inches.

A is the ordinary wood block with steel pivot, on which the brass revolving table turns. B, two brass springs which fit in holes in the table, to be used when the slide is required to be out at centre (when not in use they fit in holes in the block, as shown in the figure). H, brass ring which revolves concentrically on the table, and having two conically headed pins J exactly $3\frac{3}{32}$ of an inch apart, to allow a 3×1 slide L to be placed lengthways between them. Two similar pins F are so placed on the table, that upon revolving the ring H they, in conjunction with the pins J, firmly grasp the opposite corners of the slide, and cause the centre to coincide with the centre of the table. I is a brass pin for more easily revolving the ring on the table, and thus securing and liberating the slide. Non-centering turn-tables can be converted into self-centering ones on this plan at small cost.

Photographing Bacteria.*—K. L. Kaschka writes that the excellent photographs of Koch at first led him to believe that they could be made without great difficulty, but an unexpected difficulty was met with, so that it was impossible to find a colouring matter which would so act upon the sensitive plate as to make the bacteria print sufficiently black. Anilin colours, methyl-violet, fuchsin, and brown were first tried, but only the first two coloured the bacteria well, and although deeply coloured, as viewed by the eye-piece, they were scarcely

* Zeitschr. f. Mikr., ii. (1880) pp. 264-5. See also Amer. Mon. Micr. Journ., ii. (1881) pp. 53-4.

to be distinguished on the photographic plate, even when the latter was made very sensitive. Tincture of iodine and solutions of gold and silver salts were also tried, with negative results. Finally the cell-wall of the bacteria was subjected to a photo-chemical process in the following manner:—

After the drop containing the bacteria is dried upon the slide in the usnal manner, the spot is moistened with an aqueous solution of a metallic iodide (cadmium iodide 1 : 50 was employed), and in two or three minutes the bacteria are sufficiently iodized. The slide is then carefully and rapidly washed with distilled water, and immediately flowed with a few drops of silver solution from the negative-bath. If the right time has been hit, and the iodide has not acted for too short a period, and the washing has not been continued too long, the contour of the dried drop will be seen to show a slight yellow colour, due to iodide of silver, which is formed. Only an exceptionally short exposure to light is sufficient, after which the developer (strongly acidified and dilute iron-developer) is added, and the drop suddenly becomes black. After thorough washing the deeply coloured bacteria are mounted in balsam, and they may then be readily photographed.

This method is only useful for photographic purposes, and there is some chance of mistaking fine silver precipitates for micrococcus or other forms. In case of any doubt of this kind, the original forms should be stained with anilin colours, and examined in the usual way.

Dr. G. M. Sternberg considers* this method of staining bacteria for photographing an improvement upon Koch's method of staining with anilin violet, for the violet gives very little photographic contrast, because it permits the actinic rays to pass. A method which he has employed with success, and believes to be new, is the following:—

The bacteria are dried upon a slide, or upon a thin glass cover, and are then treated with commercial sulphuric acid, a drop of which is placed upon them. After two or three minutes the acid is washed off by a gentle stream of water, and the bacteria are then covered with an aqueous solution of iodine (iodine grs. 3, potassic iodide grs. 5, water grs. 500). After a few minutes they will be found to present a deep orange or brown colour, which gives the desired contrast in a photograph negative.

This method is only useful for extemporaneous preparations which are to be photographed immediately. The colour fades after a time, and the bacteria undergo changes in form (swelling) as a result of this treatment, which renders the method unsatisfactory when the object is to make a permanent preparation. For this purpose nothing is better than the anilin violet, which indeed leaves nothing to be desired when a collection is being made without reference to photography. The specimens should be mounted either in solution of acetate of potash (Koch's method), or preferably in carbolic acid water.

Anilin violet ink, which may be obtained from any stationer, is a cheap and satisfactory staining fluid. One or two minutes' immersion

* Amer. Mon. Micr. Journ., ii. (1881) pp. 86–7.

in this is usually sufficient time to give the bacteria a deep violet colour. Those who have not resorted to this method will be astonished at the facility with which it is practised, and with the variety of forms which may be demonstrated at a moment's notice, without a resort to culture-experiments, or to a search in ditches or sewers. The mouth, the rectum, the extremity of the uretha in the male, and the vagina in the female, are constantly supplied with an incredible number of these minute vegetable organisms, and a great variety of forms may be observed, especially in the discharges from the bowels. The slightest possible smear of saliva scraped from the surface of the tongue, of vaginal mucus, or of fecal matter dried upon a slide, stained with violet ink and washed with a gentle stream of water, will furnish ample material for study, and will serve as a practical demonstration of the extensive distribution of the bacteria.

Bacteria may often escape observation, not only because of their minute size, but because they may have very nearly the same refractive index as the fluid which contains them. Assertions therefore, as to their not being found in certain secretions, &c., will have but little value, unless it is shown that this or some other efficient method of staining has been resorted to, and the objective employed is mentioned.

Günther's Photographs of Pleurosigma angulatum.—Dr. Carpenter has engraved portions of these photographs ($\times$ 2000 and central illumination) presented to the Society by Mr. O. Brandt,* and we subjoin the four figures which he gives.

Fig. 202 A shows normal hexagonal areolation, areolæ bright circles, surrounded by dark hexagons (the "beaded" aspect).

B. In upper part, areolæ and their dark borders graduating from circular to elliptical; in lower part, dark borders coalescing laterally, so as to give the appearance of continuous vertical lineation.

C. Areolæ larger, brighter, and more elliptical, their dark borders coalescing laterally, so as to form very decided vertical lineation.

D. Transition from hexagonal to triangular areolation, with three series of dark lines, one horizontal and two oblique.

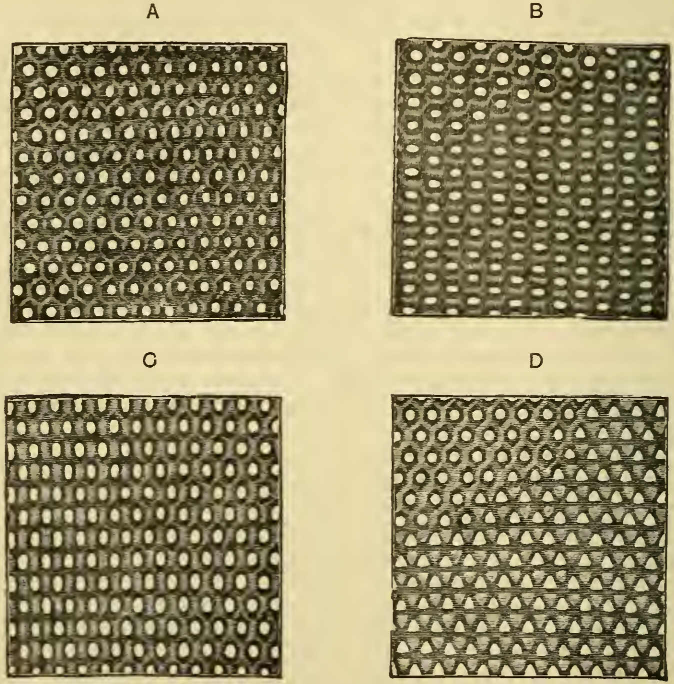
After discussing the nature of the markings of diatoms, it is added,† "Notwithstanding these considerations, however, it must be freely admitted that there is still considerable uncertainty respecting the real structure of the diatom valve. For it cannot be positively asserted that the focal adjustment which gives the image represented in Fig. 202 A, is more correct than that which gives the equally distinct images, B, C, and D, of other parts of the same valve, of which the last departs in the most marked manner from what is commonly regarded as the normal type. And now that it has been shown that these images are not formed dioptrically, but are resultants of the combination of numerous diffraction-spectra, it is impossible to entertain the

* See this Journal, iii. (1880) p. 1085.

† 'The Microscope,' &c., 6th ed. (1881), pp. 333–4.

same confidence as before that they truly *picture* the surface marking they are supposed to represent."

Fig. 202.



Cohen and Grimm's Microphotographs of Minerals and Rocks.*—The first four parts of these photographs, illustrating the microscopical structure of minerals and rocks, have now been issued. Each part consists of eight plates, with four figures on each plate, which have been selected and arranged by E. Cohen.

The photographs are beautifully executed by J. Grimm.

Braham's Lamp.†—This is simply a diminutive lime-light with a plano-convex lens in front of it, and with a rack adjustment so as to produce from the small pea of light a divergent, convergent, or parallel beam. It is also fitted to a universal stand so that it can be placed in any desired position relatively to the object.

The lamp is fed by ordinary coal-gas, the oxygen united with it being pressed through a fine jet from a bladder, sufficient for an

* E. Cohen and J. Grimm, 'Sammlung von Mikrophotographien zur Veranschaulichung der Mikroskopischen Structur von Mineralien und Gesteinen.' (Stuttgart, 1881.)

† North. Microscopist, i. (1881) pp. 202–3.

hour's illumination being made at a cost of $1\frac{1}{2}$d. The light is said to be much purer than that from any oil lamp.

Examining and Testing minute Particles of Blood.*—Dr. J. G. Richardson reproduces the method which he first published in 1875 † for this purpose.

"Procure a glass slide with a circular excavation in the middle, called by dealers a 'concave centre,' and moisten it around the edges of the cavity with a small drop of diluted glycerin. Thoroughly clean a thin glass cover about one-eighth of an inch larger than the excavation, lay it on white paper, and upon it place the tiniest visible fragment of a freshly dried blood-clot (this fragment will weigh from $\frac{1}{21000}$ to $\frac{1}{50000}$ of a grain). Then with a cataract-needle deposit on the centre of the cover, near your blood-spot, a drop of glycerin about the size of this period (.) and with a dry needle gently push the blood to the brink of your microscopic pond, so that it may be just moistened by the fluid. Finally, invert your slide upon the thin glass cover in such a manner that the glycerined edges of the cavity in the former may adhere to the margins of the latter, and, turning the slide face upwards, transfer it to the stage of the Microscope.

By this method it is obvious we obtain an extremely minute quantity of strong solution of hæmoglobin, whose point of greatest density (generally in the centre of the clot) is readily discovered under a one-fourth inch objective, and tested by the adjustment of the spectroscopic eye-piece. After a little practice it will be found quite possible to modify the bands by the addition of sulphuret of sodium solution, as advised by Preyer.

In cases of this kind, where the greatest possible economy or even parsimony of material is needful, I would advise the following mode of procedure for proving and corroborating your proof of the existence of blood, so that its presence in a stain may be affirmed with *absolute certainty*.

From a suspected blood-spot upon metal, wood, leather, paper, muslin or cloth, scrape with a fine sharp knife two or three or more minute particles of the reddish substance, causing them to fall near the middle of a large thin glass cover. Apply in close proximity to them a very small drop of three-fourths per cent. salt solution, bring the particles of supposed blood-clot to its edge and proceed as I have already directed.

After thus examining the spectrum of the substance, you may generally, by rotating the stage, cause the coloured fluid to partly drain away from the portion wherein, under favourable circumstances, should the specimen be blood, the granular white blood-globules become plainly visible, as do also cell-walls of the red disks. Among the latter, if your mental and physical vision is keen enough, you can by the aid of a $\frac{1}{25}$ immersion lens and an eye-piece micrometer

* Amer. Journ. Micr., vi. (1881) pp. 111–16, from 'Gaillard's Medical Journal.'

† Phila. Med. Times, 13th Nov., 1875, p. 78.

measure a series of corpuscles accurately enough to discriminate human blood from that of an ox, pig, horse, or sheep.

Lastly, to make assurance triply sure, lift up the thin glass cover, wipe off the tiny drop of blood-solution and clot you have been examining on the folded edge of a thin piece of moistened blotting-paper, let fall upon it a little fresh tincture of guaiacum and then a drop of ozonized ether, which will at once strike the dark-blue colour of the guaiacum test for blood.

In this way I have actually obtained these three kinds of evidence, to wit, that of spectrum analysis, that of the Microscope, and that of chemical reaction, from one single particle of blood, which, judged by a definite standard,* certainly weighed less than $\frac{1}{15000}$, and probably less than $\frac{1}{25000}$ of a grain."

Microscopical Examination of Handwriting — Detection of Forgeries by the Microscope.—We append the remarks † of Dr. R. H. Ward, of Troy, U.S.A. (President of the Buffalo Meeting of the American Society of Microscopists), on this subject, which we referred to at p. 946 of vol. ii.:—

"The examination of handwriting, with a view to determine its authorship, its genuineness, its age, and whether or not it has been altered from its original form and intent, is one of the most recent uses of the Microscope, and one, the importance, the reliability, and frequent applicability of which has but recently become known, and is even now not generally realized. Perhaps this is to be accounted for by the fact that large general experience, judgment, and tact in the use of the instrument, and skill in the manipulation, though necessary to this particular work, are not, in themselves, an adequate preparation for it. Much special study and special practice are required before anything useful can be done, or important should be attempted. But to a person really at home in the study of handwriting, both with and without the Microscope, this instrument furnishes a ready means for its accurate analysis. Those who are governed, not by respect for the rights of others, but only by the expectation of consequences that shall affect themselves, cannot learn too soon, or too well, the fact that writing can scarcely be changed after its original execution, so adroitly that the Microscope cannot detect the falsification.

The face of the paper, when once marred by disturbing the position of the fibres, can never be restored, and hence scratching and erasure can be recognized, though performed with consummate skill, and not distinguishable by other means. Inks which are alike to the unaided eye, are marked under the lenses by conspicuous differences of shades or colour, or density or purity, or chemical composition. Lines which look simple and honest may show themselves as re-touched or altered by the same or by a different hand or pen or ink; and lines drawn upon new paper may look different from those drawn after it is old. The Microscope does not give any direct information as to the precise age of writing, but if used with sufficient caution it

* See 'Handbook of Medical Microscopy' (Philadelphia, 1871), p. 283.

† Proc. Amer. Soc. Microscopists, 1880, pp. 46–8.

can determine (not so easy or safe a task as might be supposed) the relative age of superposed, crossing, or touching lines; and it can generally state positively whether lines were written before or after related erasures, or scratchings, or foldings, or crumplings of the paper. In one important case my friend, Mr. Wm. E. Hagan, of Troy, who has given extensive and very successful attention to the study of writing, especially imitative writing, and in association with whom many of my own investigations in this field during the last dozen years have been carried on, established the date of the document by recognizing in the paper, fibres which had only recently been used in paper-making, and which, in connection with corroborative proofs to which they led, demonstrated that the paper was manufactured at a later date than that claimed by the writing upon it.

To discuss the subject of imitative writing would require the opportunities of a book, not of a fraction of a lecture; and many considerations of recognized importance connected with it are still under investigation and not sufficiently mature for publication. A few hints may be given in respect to those points which are well established and most generally applicable.

When a word, in a fictitious signature, for instance, has been constructed by tracing it with pencil lines over an original one, and subsequently inking it over with a pen, particles of plumbago can probably be somewhere detected and recognized by their position and their well-known colour and lustre. The mechanical effect of the point of a pencil upon and among the fibres of the paper can also be seen, notwithstanding the subsequent staining of the paper by the ink. This clumsy method of copying carries its own means of detection, and still it is not more easily recognized than are methods that are more subtle and seem more dangerous.

In writing copied or imitated originally in ink, either by tracing it over a copy or by drawing it freehand with a copy to inspect or to remember, the distribution of ink is peculiar and suggestive, indicating hesitation from uncertainty, or pauses to look at a copy, or to recall a style, or to decide as to a future course, just at points where a person writing automatically by his own method, and especially in writing his own name or a scarcely less familiar business formula, would pass over the paper most rapidly and promptly.

Again, there are certain ear-marks, results of habit, which finally become as natural as it is to breathe, and which characterize the writing of different individuals. Such are peculiar forms and styles of letters and of combinations of letters; methods of beginning or of ending lines, letters, words, or sentences; methods and places of shading or breaking lines, and of dotting, crossing, patching or correcting; habits of correcting or not correcting certain errors or omissions; the use of flourishes; and peculiar ways of connecting words or of dissociating syllables. In imitative writing these ear-marks of another ownership are generally copied with ostentatious prominence, if not with real exaggeration, in the capital letters and other prominent parts, but lost sight of in those less conspicuous places where imitation naturally becomes feeble and the habit of the writer unconsciously asserts itself; and this revelation often becomes more positive by reason of the elaborate efforts that are made to suppress it.

Things are overdone from fear, which would have been negligently done from habit, not to speak of gross blunders proceeding from the same source. I once examined a disputed signature from which had been carefully scratched out a line, immaterial and inconspicuous, which conformed to the habit of another person interested in the case, but not to the habit of the ostensible author of the writing.

Furthermore, the genuineness of a writing may often be disproved by the very success with which it followed its copy, reproducing its mistakes, idiosyncrasies, or its adaptations to its own special surroundings, in which respects it may correspond too accurately with some one genuine signature (in the hands, for instance, of a suspected person), but differ unquestionably from the ordinary habit of the reputed author. Modifications of style by disease, as paralysis, may present similarly decisive discrepancies or coincidences. There is a peculiar tremor, too, about the writing of an individual, which is dependent on the physical conformation of the writer, as related to his habits of position, touch, and motion, which is quite characteristic, as it can be neither imitated nor concealed.

All these investigations in respect to writing can be best pursued with the aid of the Microscope, and some of them are entirely dependent upon it. For general view of the words a four or three inch objective is best adapted; for special study of the letters, a one-and-a-half inch; and for minute investigation of the nature of the lines or character of the ink, a two-thirds or four-tenths. The lenses, except the last, should be of the largest angles ordinarily made, and all should be of flat field and of the best possible definition. The microscope-stand should have a large flat stage, though it is generally preferable to use a small portable stand which can be moved freely over the paper and focussed upon it at any point without the use of a stage. For this purpose I sometimes use a tank Microscope, but more frequently a pocket Microscope, with its tube prolonged through the stage by adapters, so that it focusses directly upon the table. Even so large an instrument as Zentmayer's Histological may be so used to advantage, though a lighter form and smaller size is far more convenient and sufficiently steady for this work. A medium-sized bull's-eye is sufficient for the purpose of illumination, and good judgment is more important than, if not incompatible with, the employment of an ostentatious and unnecessarily elaborate apparatus."

Professor Lester Curtis also read a paper* before the State Microscopical Society of Illinois, in December 1879, on the "Microscopical Examination of Signatures," in which, amongst other matters, he deals with the process for determining which of two lines which cross each other was written first—the determination being easy where ink has been used, but impossible in the case of pencil, which leaves a film on the surface of the paper of an imperceptible thickness, so that no matter how many marks cross at any one place the surface is not raised.

* Amer. Mon. Micr. Journ., i. (1880) pp. 124–9.

At the meeting of the American Society of Microscopists, held at Detroit, in August, 1880, Mr. C. M. Vorce * read a paper on this subject in which he dealt with the five elements which he considers determine the character of a person's handwriting:—the paper, the pen, the ink, the personal qualifications of the writer, and the conditions under which the writing is done. Any one of these being changed from the ordinary conditions, the microscopical conditions of the writing are almost sure to be changed also.

So far as the *paper* is concerned, its glazed surface is the only characteristic which affects writing. The author illustrated by drawings the various widenings or "webs" which are always found at points where two lines cross, explaining how a variation of speed, a change in the kind of ink, and other causes affected this web. Upon rough paper the lines always have a ragged edge; the webbing is, if anything, less than upon hard, smooth, paper. As to the *pen*, when a steel one is used the paper always shows a distinct groove or cutting on its surface, especially at the edges of the heavy lines. When the pen is old and corroded the paper looks as though cut with a knife. Under the head of *ink* the various qualities were discussed. By the *qualifications of the writer*, the author includes his skill, method, physical ability, &c. A person much accustomed to writing usually writes at a good speed, and without hesitation. The writing, in quality, is apt to look alike at all points on the page. Where writing is done slowly it is not so regular, and the curves are not so smooth and geometrical. Where a habitually light writer attempts to make a heavy stroke, the shading is irregular. The same is true where a person accustomed to writing with a heavy stroke attempts to write lightly. These differences are such that they can be usually discovered with the aid of the Microscope; and when a writer concentrates all his faculties on the appearance and character of the writing, it never has the easy, flowing appearance which it otherwise would have. The tremor in the writing of old persons is nearly impossible to imitate. The *circumstances under which the writing was done* have as much to do with its appearance as any other cause. One who habitually uses a flexible gold pen writes very differently with a steel one. The reverse is equally true.

The practical application of these and other facts in the examination of writing requires patient investigation, much of it apart from the simple use of the Microscope, and the author agrees that in the great majority of cases the microscopical investigation is utterly useless without a corresponding outside investigation.

Dr. J. H. Wythe also read a paper † to the August (1880) Meeting of the San Francisco Microscopical Society, in which he said:—

"An article in the 'Banker's Magazine' for August 1878, refers to the value of the compound Microscope in the examination of handwriting, beyond the ordinary methods of experts, who rely upon unaided vision or a hand-lens. It shows that the conclusions of an ordinary expert are reliable just so far as they rest upon data which

* Proc. Amer. Soc. Microscopists, 1881, pp. 50–9.
† Amer. Journ. Micr., v. (1880) p. 225.

can be explained, and no farther. A man who writes his signature frequently falls into a series of rhythmical movements which are peculiar to himself. This may arise from habit or individuality of muscular organization. His general handwriting may differ in style from his signature, but the accentuation remains the same. A talented imitator may produce this general rhythm of a signature, and cause the testimony of an expert to become vague and uncertain. The expert may detect a difference, empirically, but he is unable to explain it to the satisfaction of a jury. 'It is just at this point,' says the writer, quoting from a letter to the 'New York Times,' 'where the methods of the expert break down, that the more delicate methods of optical analysis represented by the compound Microscope interpose to detect and demonstrate forgery.' In addition to the larger rhythm upon which the expert bases his judgment there is a *minute secondary rhythm* caused by the action of the small muscles in regulating the amount of pressure upon the pen, which is imperceptible to the naked eye, and cannot be accurately determined with a simple magnifier, but which is easily discerned in a compound instrument under a power of about ten diameters, if the writing is strongly illuminated with a good bull's-eye condensing lens. These variations of pressure are between 200 and 300 to the inch, and are as regular in proportion as they are spontaneous and involuntary. When a man writes naturally, the pressure variations are rhythmical, while on the contrary, when he is consciously imitating the writing of another, they are irregular and unsymmetrical. No matter how cleverly a signature may be imitated, so long as the writer exercises the voluntary control of the hand, which is essential to the act of imitation, just so long the margin of the stroke can be demonstrated optically to be irregular in the length and the distribution of the waves which indicate the muscular impulses. Thus the compound Microscope determines the issue at the point where the coarser processes of the ordinary expert fail. My attention having been called to this subject, I instituted numerous experiments, which have convinced me of the general accuracy of the article, of which the foregoing is an abridgment. Careful investigation enables me to classify the phenomena of handwriting, especially signatures, as analyzed by the compound Microscope, as follows:—

(1) The rhythm of *form*, dependent on habit or individual organization. This is the main dependence of the ordinary expert. It may be determined by the naked eye or a hand-lens, but is still more easily seen by means of the magnified image in the compound Microscope. In some cases an enlarged photograph of genuine and disputed signatures may be useful—remembering, however, that the form of letters may change from time to time more readily than the general rhythm.

(2) The rhythm of *progress*. This is the involuntary rhythm referred to above as pressure-variations on the point of the pen, and seen as a wavy margin to the letters of signatures when well illuminated on the stage of the compound Microscope. It is caused in all probability by the rapidly successive nerve-impulses upon which the contraction of the muscles depends. In age or infirmity, these impulses

are perceptible to the eye, and we say that the hand trembles. 'But as a matter of microscopic analysis the hand always trembles, and it is an inalienable property of muscular contraction that it should.' The regularity of this rhythm is destroyed by a voluntary effort at imitation, and is somewhat interfered with, but not entirely broken, by mental excitement. This rhythm differs in different handwritings, so that it is well for the examiner, if practicable, to accustom himself to the habitual rhythm of a genuine signature before expressing a judgment on one which is questioned.

The art of writing is a most complicated one, requiring the consentaneous action of many muscles. When perfectly performed, it should be nearly, if not quite, automatic, requiring very little mental stimulus for its performance. If any act which should be automatic demands our attention in order to execute it, the difficulty of performance increases. The ordinary mental stimulus suffers an emotional diversion, which causes proportional muscular impotence. Hence emotional disturbance causes a trembling handwriting. In cases of writer's cramp, in which the muscles respond but sluggishly to the will, and render the grasp of the pen faltering and uncertain, this rhythm is greatly exaggerated or interrupted. Paralysis of the ulnar nerve, rheumatism of the shoulder or wrist, neuralgia, and alcoholism, may also interfere with the rhythm of progress. But in no case is the failure of the rhythm so marked as in a voluntary attempt at imitation.

(3) The rhythm of *pressure*. By this I mean, not the involuntary and rapid action of the muscles, producing a microscopic wave as the writing progresses, but a rhythmical alternation of light and dark strokes, which is characteristic of some signatures, and which, in all probability, is a variety of the rhythm of form; yet, as it is revealed to microscopic analysis rather than to ordinary vision, it may escape the most expert imitator, and so become another factor in making up a judgment in any case.

If the microscopist carefully observes these three rhythms, being careful of the illumination of the letters, he cannot fail to demonstrate the difference between a genuine and an imitated signature.

In a recent trial before Judge Crane, in Oakland, I was able to discriminate between imitated and genuine signatures in a large number of cases of remarkable similarity, prepared by a most talented writer, as well as to testify to the genuineness of signatures in which there was considerable variation of form. Mr. Geo. C. Hickox, also a member of the Microscopical Society, and well known as an expert in such matters, when his attention was called to this use of the compound Microscope, declared to the Court that it was a new and wonderful revelation, fixing beyond question the individuality of handwriting, especially of signatures.

Should this method of investigation be much used, as it ought to be, it would be convenient to have a Microscope made for the purpose, having a large stage with clips so as to hold paper of considerable width, a tube of wide diameter to collect as much light as possible, a very low power eye-piece, and a special objective of long focus and large field of view."

Under the title of "Graphiology," Mr. C. H. Denison read a paper before the October meeting of the San Francisco Microscopical Society, on the art of writing, the detection of forgery, &c., in which he refers to the articles in the 'Banker's Magazine' and 'New York Times,' and denies that there is any basis for the theory suggested, the variations along the margin of signatures not being caused by any nerve-impulses or tremor, but, without doubt, by the uneven surface of the paper fabric, assisted by capillary attraction. No matter how well rolled or calendered the fabric, under the Microscope there are seen fibres and inequalities, and those depressions and swellings of the pulp cause the uneven edges of the ink. As a proof of that, he submitted specimens of ink-drops on paper, which had dried undisturbed (and upon the same kind of fabric as a signature he exhibited) the edges showing the same unevenness, and resembling exactly the edges of the signature. Straight lines drawn with a ruler upon the same fabric, with the same pen and with the same ink as the drops, exhibited similar edges. There are, he contends, no regular nerve-impulses perceptible, and therefore not comparable by individuality with each other, the irregularities seen on the margin of signatures being caused by some other principle than muscular rhythm or nerve-impulses.

After, however, the comparison of words and letters is finished, and the examination of the fabric upon which the signature or documen is written is begun, then the use of the Microscope is invaluable and certain. It is sure to detect any disturbance of the fabric by erasure, or addition, and becomes an important factor in the examination. No addition or erasure can be so skilfully made that the Microscope cannot detect it, seen either by the disturbance of the fabric, or the inequality of admittance of light through it.

Mr. R. U. Piper * also disputes the "rhythm" theory, and contends that upon the examination of the writing of the expert forger under the Microscope the sides of the ink strokes are generally found to be much more even (less tremulous) than those of the one they are intended to imitate; indeed, that this is often one of the very means by which the fraud is detected. A woodcut is given of pen-strokes ($\times$ 40) from the writing of three different persons.

At the March Meeting of the San Francisco Microscopical Society Dr. Wythe read a further paper on "Graphiology," in which he says that, "after considerable experience, I still maintain that if the microscopist carefully observes the three rhythms, being careful of the illumination of the letters, he cannot fail to demonstrate the difference between a genuine and an imitated signature.

"Since the presentation of the first article,† I have read some criticisms which remind me of the custom of neophytes, to whom we exhibit some interesting object in the Microscope for the first time. Instead of attending to the object shown, they will almost universally look at some flaw on the cover-glass, speck on the eye-piece, or accidental streak, and ask: 'What is that dark spot?' Some of these criticisms show plainly that their writers fail utterly to comprehend

* Amer. Journ Micr., vi. (1881) pp. 16–18 (1 fig.). † See above, p. 859.

the idea presented. One finds fault with the measurement of 200 to 300 in the inch given by the article in the 'Banker's Magazine,' and declares * that the irregularities are 'without doubt caused by the uneven surface of the paper fabric, assisted by capillary attraction.' The proofs relied upon for this opinion are the uneven edges of an ink drop, or of a line drawn by a ruler. From this the conclusion is reached that 'there are no regular nerve-impulses perceptible.' As to the number of the vibrations, I consider it a matter of but little importance whether there are six or six thousand. The point I endorse is, that there is an irregularity in the line which amounts to a rhythm. The irregularity produced by absorption of ink by the paper is so obvious, and so obviously different from the rhythm of progress, that no practical microscopist would be in danger of confounding them, and the veriest tyro would need no reminder.

"Another criticism † is accompanied by a woodcut of pen-strokes magnified forty diameters. An examination of this woodcut will convince any one of the difference between the irregularities of linear progress and the absorption of the "paper fabric." Differences in the irregularities of the lines are also obvious in the woodcut. If it had been magnified but ten times (as proposed) instead of forty, the rhythmical nature of the vibrations would have been more evident.

"In my first paper it was stated that a voluntary attempt at forgery leads to an exaggeration or an interruption of the rhythm. To the latter part of this statement the last criticism referred to lends unwitting corroboration. If all my critics follow in this line, my position will be well established. He says: 'The truth of the matter in this respect is, that upon examination of the writing of the expert forger under the Microscope we find the sides of the ink strokes much more even (less tremulous) than those of the one they are intended to imitate. Indeed, this is often one of the very means by which the fraud is detected.' If this language means anything different from the following, from my own paper, I am unable to perceive it. 'The regularity of this system is destroyed by a voluntary effort at imitation, and is somewhat interfered with, but not entirely broken, by mental excitement.' An 'expert forger' will destroy the rhythm of the impulses, rendering the line 'less tremulous' or smoother; but a bungler, or one whose conscience interferes, will exaggerate the rhythm.

"In my essay I sought to classify and so put upon a scientific basis facts relating to rhythms in handwriting, which any microscopist ought to be able to verify. On such a subject it would be absurd to seek for anything but absolute truth, however refined or difficult the search. Courteous criticism is therefore to be desired and not shunned. I desire this the more as I am now considerably advanced in the preparation of a book on this special subject, which will place the mode of examination within the reach of all interested."

At a subsequent meeting Dr. Wythe further enlarged upon his

* See above, p. 862. † See above, p. 862.

views * and produced some specimens in illustration, consisting of five envelopes containing the same address written by different persons.

Smoke and Steam under the Microscope.†—L. J. Bodaszewsky calls attention to the rapid oscillatory movements which are disclosed by the Microscope in the smoke of burning paper, wood, cigars, &c., when concentrated sun or electric light is thrown upon them through a lens. The particles are of a spherical form, and they are continually darting against each other, so as to represent very strikingly the motion of gas molecules according to the kinetic theory. Similar movements are observed in the vapour of nitric, sulphuric, and phosphoric acids, sulphur, ammonia, &c., when examined under the Microscope by the light of a glowing platinum wire.

Microscopical Representation of Physiological Movements.‡—M. Marey has succeeded in a further development of the Graphic Method. He has given to the tracing dimensions so reduced as to justify one in neglecting the velocity of the writing pen. Taking for example a sphygmogram or a cardiogram he shows that ordinarily the curves are about 5 mm. high; supposing that the lever moves very fast and so moves too far, if we reduce the amplitude of the tracing ten times (to 0·5 mm.) the effects of the velocity would be so much diminished as to be a hundred times less than with the ordinary instruments. These tracings must, however, be taken on surfaces which move exceedingly slowly, and the details of the curve cannot then be seen by the naked eye. When magnified ten times they can be made out. Experiments thus conducted show that the tracings are identical with those given by the ordinary cardiograph and similar instruments, in which, therefore, one may place complete confidence.

The microscopic markers can also be used to mark such delicate movements as the vibrations of the blood in the vessels, and they have a practical recommendation in being very portable, and so easily used in medical practice.

* See Amer. Journ. Micr., vi. (1881) pp. 104–8. (A discussion followed the reading of the paper.)

† Dingler's Journal. See Journ. Franklin Institute, lxxxi. (1881) p. 384.

‡ Comptes Rendus, xcii. (1881) pp. 939–41.

air. Together with the *Nitzschia* he found a *Navicula*, which moved within the sheath, and which apparently could only have entered in the form of a spore, and have developed there.

In *Schizonema* he also observed the alternate forward and backward movement of *Naviculæ* within the sheath, single frustules escaping through a small opening at the apex, which widened to allow of their passage, and afterwards contracted, showing that the membrane of the sheath must be elastic and flexible. The author came to the conclusion that the sheath-apparatus served solely for the purpose of the multiplication of the *Naviculæ*, and that the name *Schizonema* ought to be applied, not to the sheath, but to each separate enclosed frustule. He concludes that the genera *Homeocladia*, *Berkeleya*, *Encyonema*, and *Dickiea* must be identified with *Nitzschia*, *Amphipleura*, *Cymbella*, and *Navicula*.

MICROSCOPY.

α. Instruments, Accessories, &c.

Descriptions of New Microscopes.—Some of our correspondents appear to be affronted because in the accounts which we give of new Microscopes we omit by far the larger part of the descriptions usually sent us.

We do this advisedly, as we invariably give a figure, which at once dispenses with any necessity for a full description of those parts which are seen at a glance on referring to the drawing. Whilst in a catalogue or a treatise intended to describe various leading types of Microscopes, full descriptions may properly be included, it can be of no value to the readers of this Journal to have such paragraphs as this attached to a woodcut :—

" The Microscope consists of a base A in the form of a horse-shoe, in which is inserted an upright pillar B. To this pillar is attached a bar C, which by means of the hinge D can be placed in any position from the vertical to the horizontal. This bar carries at its lower end a ring E, which holds on the one side a plane and on the other a concave mirror. F is the stage," &c. &c.

For the purposes of this Journal, all that can be required in addition to a woodcut is a reference to such points as are special to the particular form.

Lacaze-Duthiers' Aquarium Microscope (Ross Tank Microscope).—This (Fig. 203) was devised by Professor Lacaze-Duthiers for use in aquaria, or for examining vertical surfaces, and has been somewhat modified by M. Nachet since the first model of 1864.

A column upon a tripod supports an arm at the extremity of which is the Microscope-body, which can be adjusted to the object in two rectangular directions by the two screws seen on the edge of the "drum" through which the tube passes. The "drum" contains the sliding metal rings by means of which the rectangular motions are obtained. The focussing is by rack and pinion (milled head shown at the side of the tube). The Microscope can also be revolved on

Fig. 203.

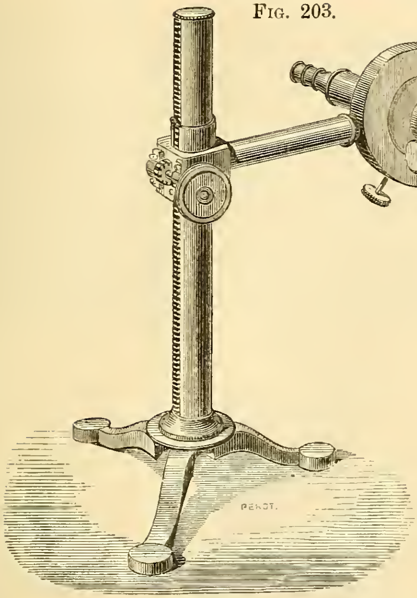
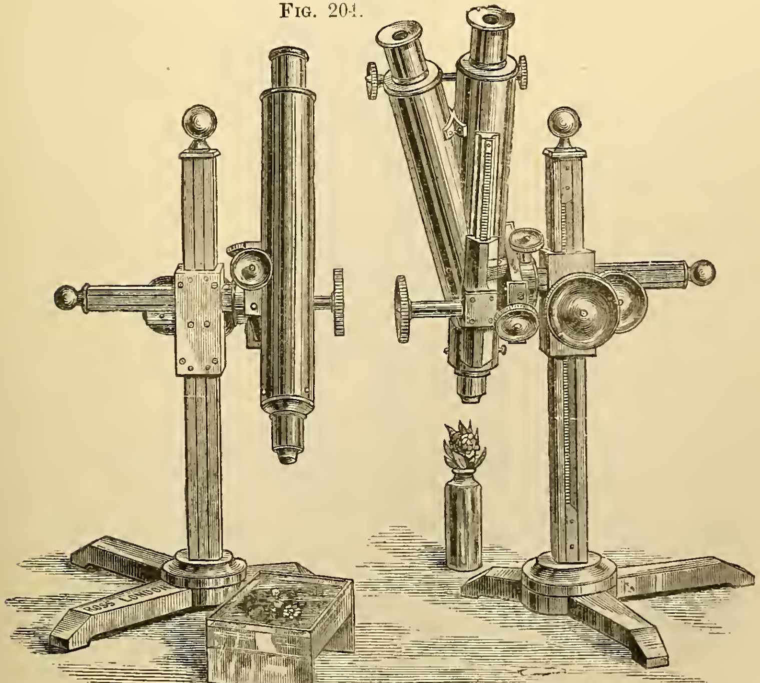


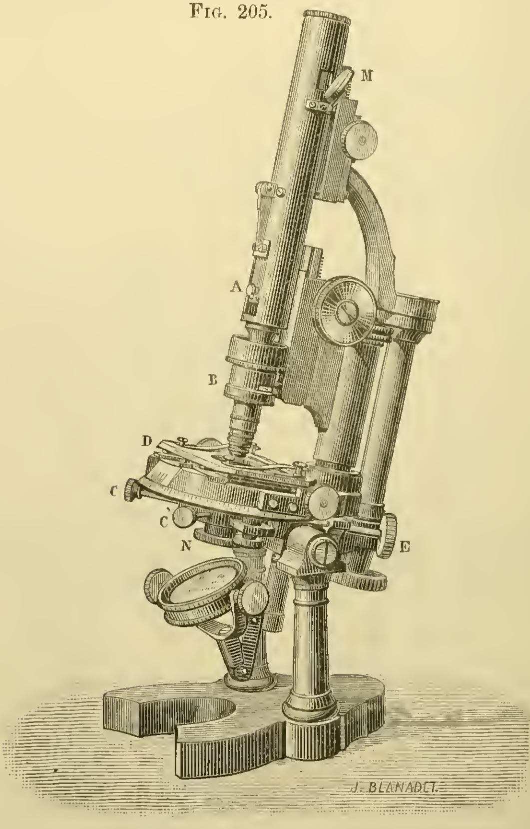
Fig. 204.



the horizontal arm, and vertical motion is provided by rackwork on the column. The rectangular motions give a moderate range within which a moving object can be kept in view.

The above arrangement is not, however, so convenient as the "Ross Tank (or "Aquarium and Physiological") Microscope," shown in Fig. 204, for examining large objects of all kinds. There is a vertical movement on the upright standard and lateral and inclining movements on the horizontal bar (the two former by rack and pinion). The two small milled heads at the side of the standard give rectangular motions to the body-tube of the Microscope, and the large one on the left is for focussing. A convenient table-stage with mirror (not shown in the figure) can be used with the instrument, or the table-tank shown under the monocular stand.

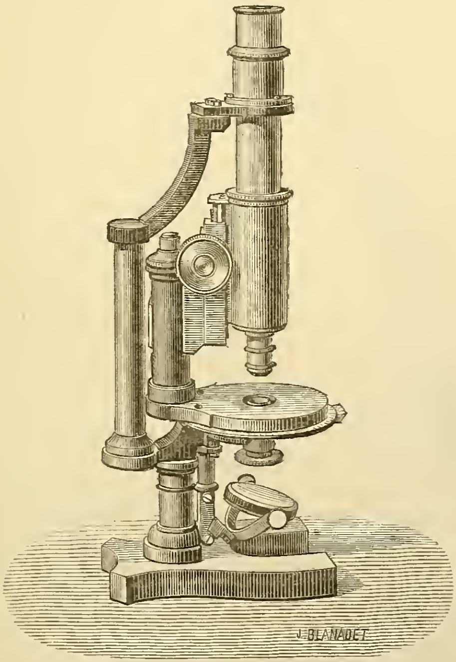
Fig. 205.



Nachet's Petrographical Microscope.—This instrument, described by M. Nachet at p. 227 of vol. iii., has been further elaborated by him, and is now issued in the form shown in Fig. 205.

The specialty of the instrument consists, it will be remembered, in attaching the eye-piece to a separate immovable arm, the body and stage rotating independently beneath it and above the fixed polarizer. This contrivance is retained in the new form, which has the following additions :—A small mirror M is placed immediately below the eye-piece, so as to illuminate the cross wires when the field is dark. The whole of the tube from A upwards is attached to the fixed arm, and is moved by a separate rack and pinion. The analyzer is inserted at A, and can be readily withdrawn when required. At B is a slit for the introduction of plates of quartz, &c. The stage is more claborate, and has a traversing object-platform D rotating in the optic axis by the pinion E, or by hand. The polarizing prism N is not attached

Fig. 206.



to the stage, and can be centered by the screens C and C′. If it is desired to use the instrument as an Amici Microscope, a cone with converging lenses can be fitted into the end of the eye-piece tube, the latter being raised or lowered by the upper rack-and-pinion movement.

A smaller form on the same principle is shown in Fig. 206.

Miller's Microscope with Telescopic Eye-piece.*—"In order to "view objects at any distance that may be required, and so obviate the

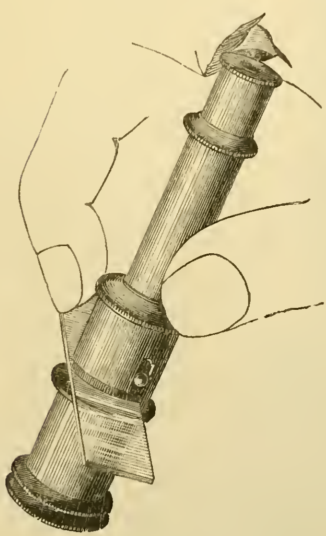
* Centr. Zeit. f. Opt. u. Mech., ii. See Zeitschr. f. Instrumentenk., i. (1881) p. 210.

"disturbing influence of the warmth of the observer's body," F. Miller substitutes for the ordinary microscopic eye-piece a telescope adjusted to parallel rays whilst the object is in the focus of the objective of the Microscope. The distance of the eye-piece of the telescope from the objective of the Microscope is immaterial; the image of the object always appears sharply defined.

Salt's Pocket Microscope * (Swift-Brown Pocket Microscope).— We take from the 'Lancet' the following description (modified to meet subsequent alterations) of a small pocket Microscope, by Salt and Son of Birmingham (Fig. 207) for the examination of urinary deposits, blood, &c.

"The stand and mirror hitherto deemed essential in all compound Microscopes are dispensed with. A lens is placed at the end of the Microscope, which when the instrument is held up to a window or lamp, concentrates sufficient light upon the slide to render all objects in the field distinctly visible. Even on a dull day in London we have found the illumination thus obtained amply sufficient. The Microscope is a compound achromatic one, furnished with a $\frac{1}{4}$-inch objective having a magnifying power of 120 diameters, and a sliding tube of short range for adjusting the focus. In using the instrument it is intended that a few drops of the suspected urine are placed between two small glass slides, which are then placed in a deep notch in the lower part of the Microscope. They are fixed *in situ* by a sliding tube [ordinarily pressed downwards by a spring, but which can be withdrawn within the upper tube (by the projections working in slits on either side) when it is desired to change the object]. The Microscope is then applied to the eye, as shown in the engraving, and the focus adjusted.

Fig. 207.



"It is an ingenious little instrument, very compact, measuring only five inches in length, and its case is scarcely bigger than that of a fair-sized urinometer. We can thoroughly commend it not only for convenience, but, when properly used, for efficiency also. It is well adapted for the examination of the blood; an excess of white corpuscles can be at once distinguished by its means. It is also, when properly employed, very useful for the examination of the urine; but used in the method recommended by Messrs. Salt, it is almost valueless for this purpose. It is true that if a urine were loaded with pus, this could no doubt be

* 'Lancet,' Jan. 29, 1881, pp. 188–9 (1 fig.).

readily discovered in the manner above described; but if the urine contained a few blood-corpuscles or casts, they could not be thus discovered. The film of liquid held between two [small-sized] glass slides by capillary attraction is so extremely thin that objects sparingly contained in the urine would not be discovered. If, however, a small cover-glass be used, and the movable tube be placed above the slide so as to clamp it from above instead of from below [this we understand to have been carried out in the newer form], and thus avoid pressing the cover-glass against the edge of the notch, a thicker film of liquid is examined, and the instrument answers very well. But its utility would be greatly increased if a plane mirror were fixed in a removable tube at the end of the instrument, so that it could be used in the upright posture as well as, if desired, in the horizontal. All practitioners know how desirable it often is, in examining a urinary deposit, to have a very thick film of liquid, and this is impossible unless the Microscope is vertical in position."

The difficulty we have found with this instrument is the great want of light, notwithstanding the condensing lens; and it cannot, we are bound to say, be compared with the small pocket Microscope designed and made by Mr. Swift and described by Professor G. T. Brown (Figs. 208, 209), which is more compact—3 × $\frac{3}{4}$ inch —and is far more convenient to use. It is provided with a mirror G, which can be removed when desired, and the piece which is seen projecting on the right enables full-sized slides to be used. It has also an achromatic condenser with diaphragm for oblique light as well as dark spots; and according to our experience, hardly leaves anything to be desired where an instrument is necessary which has to be in reality, and not in name only, a "pocket Microscope." (A is the main outer tube; D an inner tube carrying the objective and sliding within A for the coarse adjustment; E a third tube which supplies a fine adjustment. Within B is a spring tube which holds the slide C in position.)

FIG. 208.

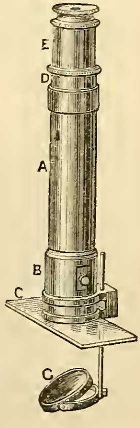
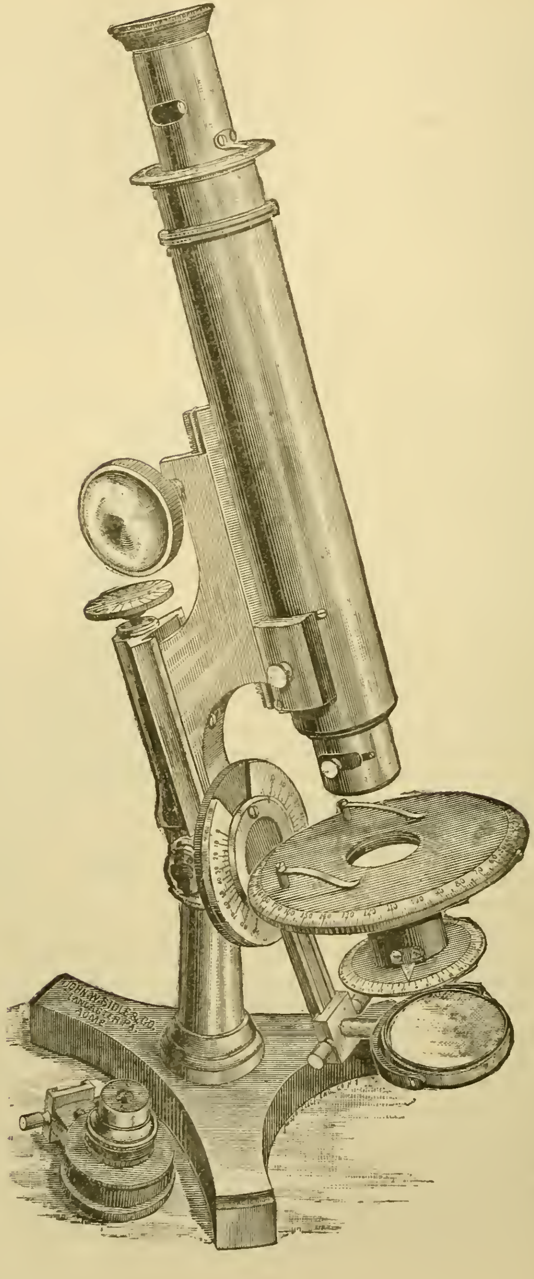


FIG. 209.

Sidle's "Acme" Lithological Microscope.—This (Fig. 210) is on the general plan of the "Acme" models (see vol. iii. (1880) p. 522, and *ante*, p. 657), but in lieu of the rotating stage-plate there is a permanent *rotating stage* graduated to degrees.

The *polarizer* is mounted on swinging arm to allow of being turned out of the way when not in use, and is furnished with a graduated circle and index, and a spring click showing when the prisms are crossed. It will receive a lens-system of extreme angle at its upper end, which, together with a corresponding system adaptable to the $1\frac{1}{4}$-inch screw in body-tube, serve to show the rings

Fig. 210.



and crosses in crystals. An *analyzer* and a *Klein's quartz-plate* are mounted in sliding boxes in the lower end of the body, each admitting of removal when their respective openings may be closed by sliding shutters provided for the purpose. An extra analyzer is mounted to slip over the eye-piece, and is furnished with a graduated disk with index.

For stauroscopic measurements a *double calcspar plate* is arranged to rotate between the analyzer and eye-lens.

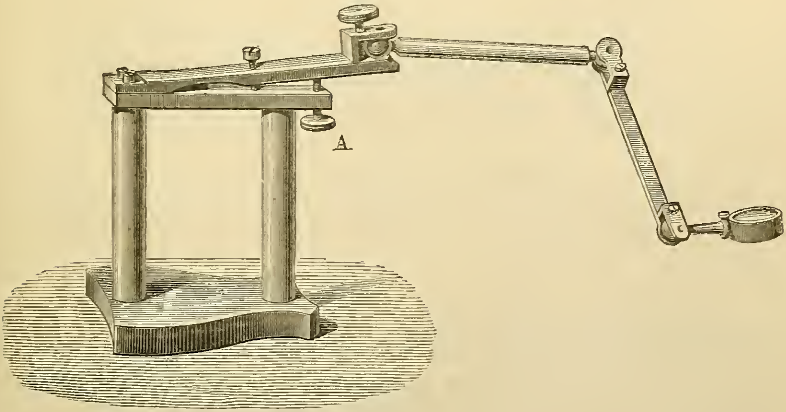
The eye-piece is also provided with *cross lines* ruled on glass.

The instrument can, of course, be readily converted into an ordinary monocular when not required to be used for its special purpose.

Browning's Platyscopic Lenses.—An addition has been made to this series of achromatic pocket lenses by a new one of lower power—magnifying 10 diameters—and larger field than has previously been made. The series now consists of lenses magnifying respectively 10, 15, 20, and 30 diameters.

Nachet's Porte-loupe.—This (Fig. 211) is substantially a modification of Strauss-Durckheim's lens-holder, the movements of the

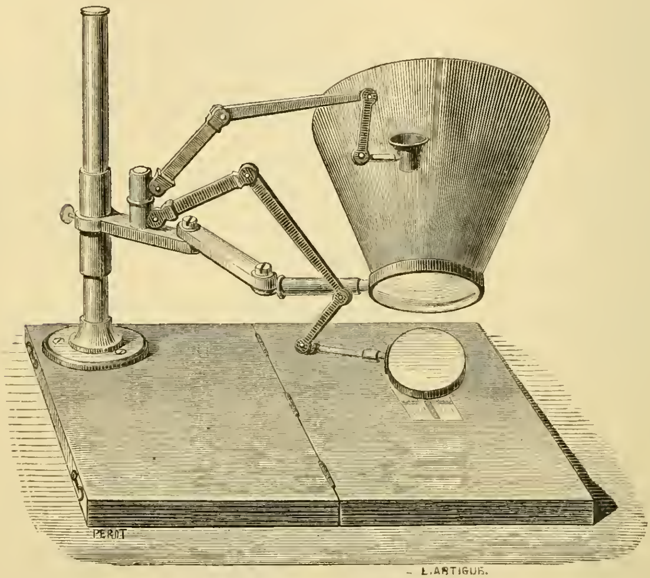
FIG. 211.



arms (which are articulated by balls held between claws) allowing the lens to be readily placed in every position. By the screw A, a fine adjustment is obtained.

Lacaze-Duthiers' Porte-loupe.—This (Fig. 212), also made by MM. Nachet, consists of three articulated arms attached to a horizontal support, and the latter to a standard, as shown in the figure, the whole of the arms together being movable vertically or horizontally. Two of the arms are fixed to a piece of tubing sliding on the horizontal support, and carrying lenses of different powers, while the third has a bull's-eye condenser, to which can be fixed a funnel-shaped piece of blackened paper, to act as a screen. The box in which the apparatus packs serves, when opened flat, as a base.

Fig. 212.



The speciality of the apparatus appears to consist in the numerous articulations of the arms (which allow the lenses to be readily placed in any desired position), and its portability—35 cm. square by 7 cm. deep.

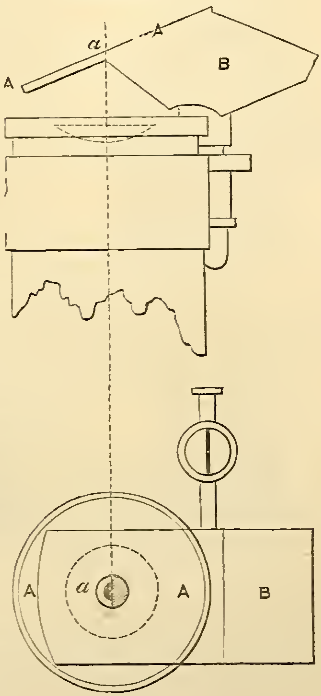
Zeiss's Camera Lucida.—The following is a translation of the revised directions for using this instrument (see *ante*, p. 818):—

The apparatus having been attached to the Microscope by the "sprung" ring, turn back the prism round the vertical pin so as to allow the eye-piece to be inserted and the preparation adjusted. Afterwards the prism must be brought into the position indicated in Figs. 213 and 214 by the revolving motions round the vertical and horizontal pins, also by the horizontal and vertical sliding movements of the same pins, or where requisite by the ring as well.

As is shown by the figures, the circular opening *a* in the upper plate A A of the camera should be concentric with the eye-lens of the eye-piece. The small bright circle, which is seen above the eye-piece when the eye looks down upon it from some height in the direction of the axis of the Microscope, must then appear, approximately, *half* covered by the glass prism visible through the opening *a*. Seen from the side, the plate A A must also be inclined to the axis of the Microscope, and the body B of the camera be placed as near as possible to the eye-piece.

Having made the adjustment approximately according to these directions, on looking down the Microscope and keeping the pupil of the eye exactly over the edge of the prism, there is seen within the field of view, and simultaneously with the microscopic image, a portion of the surface of the table, that part which lies near the foot of the instrument on the side of the prism B. If the camera has been put on with B to the right of the observer, the space which becomes visible is to the right of the Microscope; but if the camera is turned towards the front, as may be done when the light falls on the Microscope from one side, the space in front of the instrument will be projected into the field of view. Upon that part of the table which thus becomes visible must now be placed the drawing-paper in such a manner that it rests upon a support inclined towards the Microscope about 15° to 20°, so that the plane of the paper lies approximately parallel to the plate A A of the camera. If, after the camera has been adjusted as above directed, the field of view, on looking down the Microscope, appears obscured on either side by a glare of colour; or if the drawing surface is only visible in a part of the field of view, the imperfection may be cured by turning the camera very slightly round the vertical or horizontal pin, testing it in one or other direction whilst looking through it.

Figs. 213 and 214.



Tighlmann's Cylinder-Diaphragms for the Vertical Illuminator.—The vertical illuminator is shown in Fig. 215 (actual size) with Mr. Tighlmann's cylinder-diaphragm. The diaphragm consists of a short piece of cylindrical tube, from which about one-third of the circle is cut out, made to slide at will as an outer jacket over the circular aperture through which the illuminating rays pass to the plate of glass which is adjusted (within the adapter) in the optic axis and inclined 45° so as to reflect the rays to the objective from above—the objective thus serving as illuminating lens. The square end of the sliding cylinder, passing variously over the circular aperture, cuts off larger or smaller segments of the opening either vertically

Fig. 216), or horizontally (Fig. 217), and two small apertures give additional facilities for varying the effects (Fig. 218). The apparatus was constructed for Mr. Tighlmann by Messrs. Queen, of Philadelphia, U.S.A., and can be commended for its simplicity. The milling on the moving cylinder should, however, project much more, so as to present a better grip for the adjustment. The cylinder should also be lined with cloth to diminish the friction in moving. The vertical illuminator is seldom used except with high-power objectives, and it requires very delicate manipulation; unless, therefore, the diaphragm can be moved with a light touch, the image is apt to make bewildering excursions—especially when the apparatus is used with a Microscope focussing at the nose-piece. One of the principal considerations to be held in view in the application of diaphragms to illuminating devices should be to enable the observer to watch the effect produced during the actual movement of the diaphragm. The accurate discrimination of the more difficult images with high powers is so largely dependent on

Fig. 215.

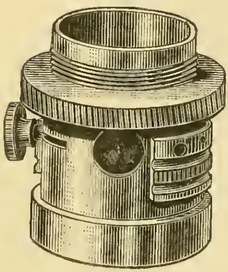


Fig. 216.

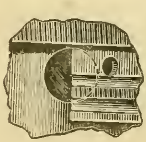


Fig. 217.

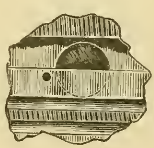
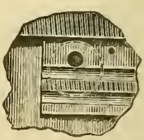


Fig. 218.



the convenient arrangement of the means for slightly varying the illumination, that we should consider any device defective in so far as it could not be controlled by the observer without removing his eye from the eye-piece.

Mr. Tighlmann's new diaphragm appears to us capable of developing the power of the vertical illuminator beyond the point hitherto attained.

New Homogeneous-immersion 1-12-inch of 1·43 N. A.—Mr. T. Powell has constructed a homogeneous-immersion $\frac{1}{12}$-inch objective of 1·43 N. A. without mounting the front lens on thin glass as described in this Journal, vol. iii. (1880) pp. 884 and 1050. The mounting of the front lens on a plate of glass of only ·003 in. thickness is obviously not a very secure method, whilst it necessitates special care in the use of the objective.

Fluid for Homogeneous-immersion.—Prof. Abbe has tested the chloral hydrate in crusts suggested (with glycerine) as a fluid for homogeneous immersion by Mr. Basset,* but finds, on examination of various solutions of the substance by the refractometer, that it is not one for strictly homogeneous immersion, as it does not give as high a refractive index as oil of cedar-wood, even in its most concentrated form. Liquefied by the smallest possible quantity of glycerine into a very thick pap, it does not give a higher refractive index than 1·510 (at a temperature of 15° C.), which may therefore be taken very approximately as the true index of the *pure* chloral. Every practicable solution (even 10 or 20 parts to one of glycerine) must therefore have a lower refractive index than 1·510 and thus leave a slight defect of refraction, in comparison with ordinary crown (1·520), which is possessed by cedar-oil.

Beck's Glass Friction-stage.—This (Figs. 219 and 220) is a simple form of friction-stage for application to Student's Microscopes. The base-plate is circular and of brass with a deep rim to give

Fig. 219.

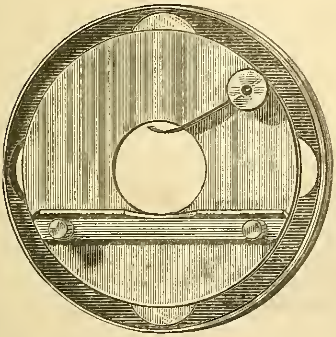
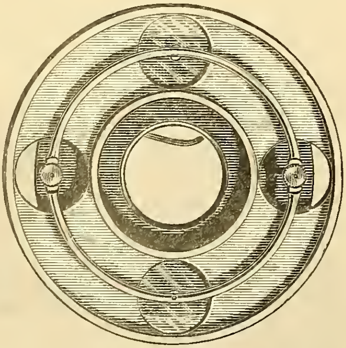


Fig. 220.



rigidity. In addition to the usual central opening there are four other circular openings of about $\frac{7}{8}$ inch in diameter, one in each quadrant. A polished glass plate is imbedded on the surface of the base-plate, having a central opening and two circular openings corresponding to those in one diameter of the base-plate. An upper brass plate, on which the object-slide is placed, has a piece of velvet cemented to its under surface, and it is held in contact with the glass by a strong wire ring beneath. Fig. 220 shows the under surface of the stage, and it will be seen that the upper brass plate (darkly shaded) is attached to the ring by milled-head screws passing through the right and left openings in the stage; the other two quadrants of the ring are provided with small ivory knobs which make friction-contact with the under surface of the glass plate (shown slightly shaded), through the other two openings in the base-plate. About $\frac{3}{4}$ of an inch of motion in all directions is thus allowed for the upper plate, and the movement is extremely smooth—the friction above is between

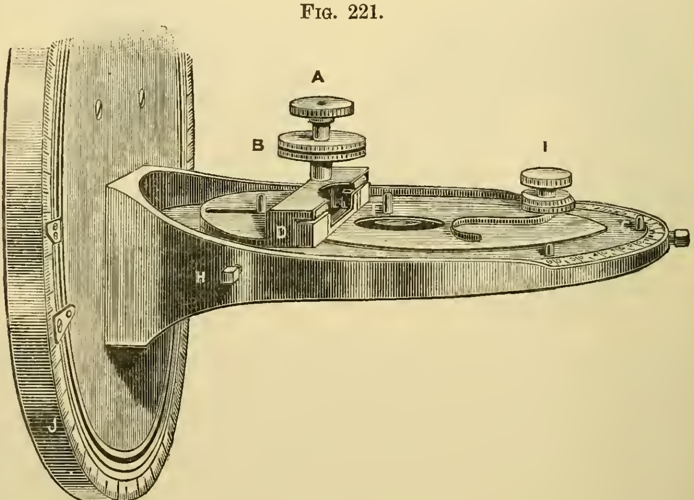
* See this Journal, *ante*, p. 123.

the velvet and the polished glass, and below between the ivory knobs and the glass surface. The friction can be somewhat increased by tightening the milled-head screws. An adjustable spring-clip keeps the object in position.

Tolles's Mechanical Stage.—Mr. Tolles has now further improved the stage described pp. 116–118 (Figs. 9 and 10). The improvements are comprised under four heads:—(1) The application of a rim or flange to the main stage-ring or support *above* the general plane of the stage. (2) The countersinking of the rotating stage-plate into the stage-ring. (3) The use of *one* plate only for the rectangular motions of the stage. (4) The union upon *one* axis of the milled heads controlling the rectangular motions.

(1) The upper surface of the main stage-ring H was formerly flat, and formed a bedding for the rotating plate C, the milled edge of the latter projecting slightly, for convenience of turning by the hand: a rim or flange is now applied to the ring H, outside the plate C, and is carried up to the shoulder by a gradually

Fig. 221.



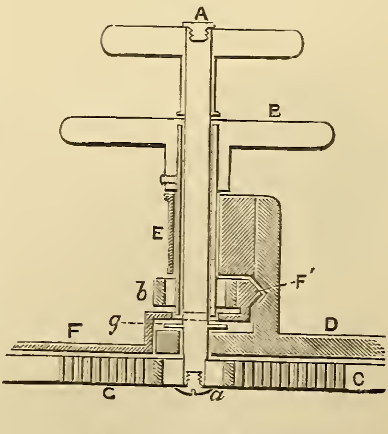
increasing vertical thickness of metal, by which the rigidity of the stage is considerably added to. The shoulder forms a substantial attachment to the vertical disk which is fixed to the limb of the Microscope, and in which the substage and mirror slide laterally, concentrically with the object upon the stage (see Mr. Tolles' special form of traversing substage figured vol. iii. (1880) p. 521). Mr. Tolles' plan of making the rectangular and diagonal movements act completely *within* the circumference of the stage, has enabled him to strengthen the rim of the stage-ring *above* the general plane instead of *below* it; the inner part of this ring-support is flanged so that the rotating stage plate is countersunk flush with the thinnest part of it—the perpendicular thickness of the working part of the stage, i. e. from the surface of the object-plate to the under surface of the ring which limits the free admission of oblique light, laterally or in front, is hardly more than one-eighth of an inch, and yet the rigidity is greater than in the previous model, where the thickness was about half an inch.

(2) As stated above, the rotating plate C, formerly rested on, and projected slightly beyond, the surface of the stage-ring H; it is now countersunk to the thinnest level of the stage-ring, and the graduations are advantageously made on the surface, where they can be more readily inspected. Small knobs are applied on the surface, near the edge, for convenience of turning by the hand.

(3) In the former model, the stage motions were obtained by means of two plates of German silver, each about 1-50th inch in thickness; the new model dispenses with the lower plate altogether (as first suggested by Mr. Wenham), the plate F, traversing horizontally in the box-fitting D, by means of a rackwork at its lower edge, and acted upon by the toothed pinion of the milled head B, whilst the vertical motion is given by the toothed pinion of the milled head A, gearing into a vertical slot rackwork in the rotating plate C,—the box D, with the pinions, and the plate F, moving together, all carried on a dove-tail plate sliding in a corresponding slot cut in the rotating plate, certain guide-pieces (like the peg shown behind D) serving to prevent lateral rocking.

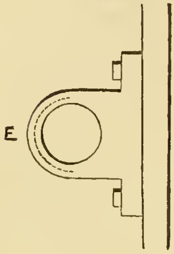
(4) In the earlier model the rectangular motions were each controlled by a pinion and milled head on separate axes: now they are combined upon the *same* axis. The milled head A, attached to a solid pinion passing through the box D, is held beneath the rotating plate by a screw and friction-washer, and gives vertical motion, as explained under (3); the milled head B is attached to a hollow pinion (encircling the solid one) fitting in a ring fixed within D, and gives horizontal motion to the plate F, as noted under (3); the fittings of these pinions are so arranged that the motions are quite independent. In this last improvement (as applied to this form of stage) Mr. Tolles has been preceded by Mr. Wenham and Messrs. Watson.

Fig. 222.



The mechanism of the stage-movements will be understood by reference to the section drawings (Figs. 222 and 223). In Fig. 222, A is a milled head attached to the inner arbor, communicating motion to the toothed pinion a, which works in the rack G attached to the revolving plate C, and, travelling along the rack, gives vertical movement to the plate D, and also to the plate F on which the object-slide is placed. F and F′ are in one piece or connected. The pinion head B controls the hollow arbor surrounding A, and forms part of *b*, which gears into the toothed face of F′ and gives horizontal motion to F and F′—the upper plate (at F′) slides in a groove in the plate D bent upwards from this latter, and solid with it.

Fig. 223.



A, *a*, and D are made to work independently, and would be unaffected if all the mechanism of the horizontal motion were removed, i. e. there is *no friction* between the two arbors or parts. The milled head, arbor, and pinion A, are held firmly in D by the flange *g*, and by the pinion itself; the required tightening is given by the screw shown in the lower end of the arbor, and the pinion itself is shouldered on and clamped to the arbor.

Fig. 223 shows a top view of the box, or bearing, within which the hollow arbor E works, attached to the vertical moving plate D.

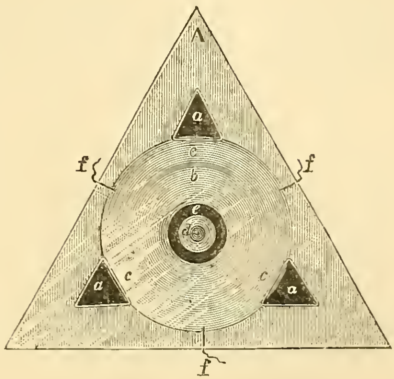
The special feature of the improved stage appears to be the gain in rigidity by the application of the rim or flange *above* the general plane —indeed it would now appear that the flexure, hitherto a serious drawback in all mechanical stages permitting a large range of obliquity of incidence beneath, is thus practically overcome. The new shaped rim does not in any way interfere with the rectangular and rotatory motions of the stage, whilst, instead of adding to the thickness of metal beneath the plane of the object, it has, on the contrary, enabled Mr. Tolles to reduce this perpendicular thickness to practically *nil.* The hemispherical immersion illuminator is applied to the under surface of the rotating plate C by a screw thread; the plane surface of the lens is then flush with the surface of the object-plate F, and the stage is so thin that upwards of 160° of the hemispherical surface is exposed beneath; dark field illumination could thus be obtained, even with Powell and Lealand's homogeneous-immersion $\frac{1}{8}$ of 1·47 N. A. (150° in crown glass).

Goodwin's Growing-slide.—This slide was designed by Mr. W. Goodwin with the view of obtaining one in which the objects should be capable of being placed as much as possible under normal conditions as regards the supply of water, &c.

It consists (Fig. 224) of a triangular plate of glass A, the sides of which are the ordinary length of a slide (3 inches). Upon this are cemented three pieces of ebonite *a*, the inner surfaces of which are cut in a curve so as to allow a thin glass cover *b* to lie freely but closely between them. There is an indiarubber band *c* round each stop which projects a short distance across the cover, and prevents any movement of the latter when once placed in position. In the centre of the cover a small hole *d* is drilled, and round this hole is a metal ring *e*. Under the edges of the cover are placed three threads *f*.

The action of the slide is as follows:—Placed in a horizontal position beneath a thread of soft cotton which is connected with a vessel of water, the water by capillary attraction and gravity runs down the cotton and falls drop by drop upon the centre of the cover, and quickly makes its way through the hole to the under side. When the space beneath the cover is full the water will then have reached the threads at the edge, and will so be drawn off. There is thus a constant flow of water supplied by the thread above and carried off by those at the edge of the slide.

Fig. 224.



Objects may be introduced into the slide through the hole in the cover, being first taken up in the dipping tube and allowed to flow slowly through the hole, and so under the cover.

A number of slides may be in operation at one time, it being possible to arrange as many as ten or a dozen round a base from which threads convey the water to each slide.

The slide was described by Mr. T. Charters White (at the last meeting of the Society *) as the best form which he had yet worked with.

Diaphragms for Axial Condensers.—At p. 667 it was stated that "no disposition of diaphragms has yet been applied to condensers used in the axial substage to enable us to regulate the *amount* of light without altering the *obliquity*."

Fig. 225.

With the simple diaphragms, however, shown in Fig. 225 (which were, we think, originally used by the Rev. J. B. Reade, with his "kettle-drum" illuminator) the obliquity of the light is unaltered when the upper diaphragm is rotated over the lower, or *vice versâ* (the lower indicated by dotted lines), while the amount is regulated axially at pleasure, from the maximum when the two slots coincide to an almost infinitesimal pencil when they are separated.

New Dioptrical Formula.†—The following is published by the French Academy on the report of Messrs. Fizeau, Jamin, and Cornu. The authority is Mr. C. V. Zenger.

"It is acknowledged that the abridged dioptric formulæ do not furnish results sufficiently exact for them to be employed in the construction of aplanatic and achromatic objectives.

* See *post*, p. 979.

† Comptes Rendus, xciii. (1881) pp. 398–9.

Hence it is that all the celebrated opticians have had recourse to trigonometry for calculating the direction of the refracted rays, and I have done the same myself. But I have been able to formulate the results thus obtained, on account of the small difference in refraction which is found in the different kinds of glass, crown and flint, and have constructed tables which give in algebraical form the relation between the radii of curvature and the indices of refraction of the two media which enter into the construction of the objective, whether microscopic or telescopic.

The formula only contains the indices of refraction of the two media n and n', their relative dispersion $\frac{dn}{dn'}$, and some constants the value of which depends solely on the index of refraction of the least refractive medium. But what is more important is the fact that by the help of this formula the problem can be reversed, and we can find the indices of refraction and the dispersion necessary to render the double lens aplanatic and achromatic.

With the help of the tables I have constructed and the formula referred to, I have found that the best results are obtained when the following conditions are fulfilled.

1st. The dispersion should be such that $\frac{dn}{dn'} = 0 \cdot 5$, and this relation should be the same for all the partial dispersions from red to violet. Then the achromatism is perfect.

This condition can be realized by a mixture of aromatic substances, of which some react more on the red whilst the others, on the contrary, enlarge the violet part of the spectrum. By mixing two or three substances we can obtain the refraction and dispersion given by the formula for making the objective aplanatic and achromatic.

2nd. The index of refraction of the mixture should be $n' = 1 \cdot 63242$, for example, when the crown-glass used in the construction has an index $n = 1 \cdot 5296$. The formula gives the change in n' for any other value of n.

3rd. All the radii are then identical. Hence I call the objective *symmetrical*, for the last radius $r_4 = \infty$, that is to say the last surface becomes a plane surface.

Any one can make his own telescope or Microscope without any calculation by taking a lens of quartz or crown-glass of any description and the mixture of aromatic bodies which gives to it a dispersion twice as great, or equal for all the rays of the spectrum.

We obtain the lens of the Microscope by reversing this lens, that is to say, the plane surface is placed on the side of the object.

The lens being corrected, it is combined with one or two other symmetrical lenses in the well-known mode, by which doublets and triplets are obtained perfectly aplanatic and achromatic; then, on going beyond the focus either way, no trace is found of the secondary spectrum.

The test objects which I have used are globules of mercury on a black ground, with sunlight, and the plate of M. Abbe of Jena, viz. a plate of silvered glass ruled with cross-lines in different directions.

A dazzling white is alone seen on a black ground, without the slightest trace of the colours of the secondary spectrum.

I consider that this is the method to be followed to solve the problem of absolute achromatism of objectives both for the telescope and the Microscope."

Refractive Indices of Optical Glass.*—A table of refractive indices has recently been published under the heading of "Fraunhofer's Table of Refractive Indices," in which the following are the figures given for crown and flint glass for the lines C and G:—

Crown:—		
Chance's soft	1·5119	1·5263
„ hard	1·5146	1·5280
No. 13	1·5253	1·5399
No. 9	1·5268	1·5416
M.	1·5559	1·5736
Flint:—		
Chance's light	1·5700	1·5922
No. 3	1·6038	1·6308
Chance's dense	1·6175	1·6453
No. 30	1·6255	1·6554
No. 23	1·6284	1·6588
No. 13	1·6297	1·6603

These figures, however, require considerable supplementing, as in the present day glass is used for optical purposes, notably by Zeiss for microscope objectives, the index of which far exceeds anything given in the above table, being as high as 1·8017 for flint † for the D line. The flint is not perfectly white but slightly yellowish, which is not, however, perceptible in the small pieces used for the lenses of microscope objectives. We believe also that Messrs. Chance make a double-extra-dense flint of 1·71–1·72 index.

Fine Rulings.—We noted in vol. iii. (1880) p. 891 and *ante* p. 544, the alleged issue of rulings on glass of an almost fabulous degree of fineness. Mr. Fasoldt now writes ‡ as follows:—

"There seems to be some misapprehension in regard to my claims for fine ruling up to 10,000,000 lines per inch. The truth is, I have never claimed to rule that figure. I believe I once communicated the fact that my ruling-engine had an index capacity of 10,000,000, but it was necessary to arrange it thus in order to facilitate the subdivision in the lower figures.

"I have ruled plates up to 1,000,000 lines to the inch, one of which was purchased by the U. S. Government at Washington. These plates show lines truly and fairly ruled, as far as lenses are able to resolve, and above this point the spectral appearance of the bands in regular succeeding colours (when examined as an opaque object) shows, beyond doubt, that each band contains fairly ruled lines up to the 1,000,000 band.

"Dr. Ward seems to think that the simple setting of the register

* Engl. Mech., xxxiv. (1881) p. 56. † As low as 1·5017 for crown.
‡ Amer. Journ. Micr., vi. (1881) p. 163.

of a ruling-engine to the $\frac{1}{10}$ or $\frac{1}{10000000}$ of an inch, is all that is required to produce a ruling. I know that very many other conditions must be satisfied to produce perfect rulings.

"I do not believe that I will ever attempt to rule higher than 1,000,000 lines per inch, as from my practical experience and judgment I have concluded that that is the limit of ruling."

Whether 1,000,000 lines to an inch have really been ruled must remain an unsolved problem, for, as Prof. Helmholtz has shown, that number is very far beyond the limit of resolution.

β. Collecting, Mounting, and Examining Objects, &c.

Koch's New Method of Pure Cultivation of Bacteria.*—During the recent meeting of the International Medical Congress Dr. Koch explained the methods he had adopted in his researches into the relation of Bacteria to disease, and amongst them was a new and simple method of obtaining pure cultivations of the species of Bacteria, which Prof. Lankester considers to be "likely to mark altogether a new era in the study of the relations of Bacteria to certain diseases," and the determination of what effects are due to one species of Bacterium and what to another. To effect the separation of species in a mixture, Mr. Lister employed a method of dilution and division,† using a *fluid* as the nutrient medium of cultivation, as hitherto has been the almost universal practice. This method is tedious and liable to failure owing to the great care necessary to ensure and maintain sterilization of the cultivation fluid whilst exposed for the purpose of inoculation, and again for further examination. Dr. Koch's new method of cultivation essentially consists in the substitution of a *solid* for a fluid medium, and he was led to it by the use of the method, known to all mycologists, of cultivation upon slices of potato or beet-root. It is readily observed, when slices of boiled potato are exposed in a damp condition to the atmosphere, that the surface of the slice becomes the seat of development of various Bacteria and of moulds, the spores of which fall from the atmosphere on to the exposed slice. A fact which struck Dr. Koch as of importance in reference to the slices of potato was this, that the various spores falling on to it remain where they fall, and from the spot where each spore or germ originally fell it proceeds to multiply, producing around it a symmetrical hemispherical growth of perfect purity. In fact, owing to the solid character of the nourishing support, the germs and spores cannot get mixed as they do in a liquid; each remains distinct from its neighbour, even though in very close proximity, and without any trouble from the resulting growth which proceeds in a day or two from each germ, new and perfectly pure cultivations may be started in suitable sterilized fluids.

Dr. Koch's method consists in substituting for the potato slice a layer of gelatine, which is so saturated with water as just to become solid on cooling. The gelatine liquid is readily sterilized by boiling, and into it can be introduced either Pasteur's salts, peptones, blood-

* Quart. Journ. Micr. Sci., xxi. (1881) pp. 651-4. † Ibid., xviii. p. 191.

serum, or other nutrient material required by one or other species of Bacterium. The gelatine-medium thus prepared may be kept in a tube and a cultivation thus carried on upon its surface, or (and this is its principal use) it may be spread when liquid on a microscope object-slide and allowed to cool. Then such a gelatine plate may be inoculated by touching its surface with material containing the Bacteria which it is desired to study. The plate is readily protected from the access of accidental atmospheric germs, and maintained at such temperature and degree of moisture (by a glass shade) as the experimenter may desire. The main point of advantage is this, that the point of inoculation on the surface of the gelatine can, owing to its transparency, be readily examined with the highest powers of the Microscope, and the growth of the Bacteria followed; whilst further, owing to the fact that the medium in which the growth takes place is solid, no mixture of the different kinds which may be present occurs, but each Bacterium produces around it a little spherical nest of its own kind. From these nests, with a sterilized needle-point, individuals can be removed to start new pure cultivations.

But it is obvious that, if the original point of inoculation was very minute, there is no danger of any accidental contamination from atmospheric germs, for these are not likely to fall on the identical spot no bigger than the puncture of a needle's point, where the experimental culture is going on. As a matter of fact, where they fall on to the gelatine there they remain and grow, and fifty such accidental spores may fall on to the gelatine plate without in the least interfering with the purity of the experimental culture.

There is yet further a very simple device which enables Dr. Koch to use this gelatine surface as a means of "spacing" and dividing the various species in a mixture of Bacteria. He dips a sterilized needle into such a mixture, and then makes a long shallow streak with the needle's point upon the surface of the gelatine. The Bacteria which were adhering to the needle's point are in this way dropped at intervals along the streak, some nearer, some further apart, but all (with rare exceptions) in such a way that their subsequent growth keeps clear of that of a neighbour, and can, with the aid of a low power or even without any Microscope, be visited by a sterilized needle-point, and thus used to start on another gelatine plate a perfectly pure cultivation.

"It is only by such monosporous cultivations," writes Professor Lankester, "that we can arrive at solid conclusions in reference to the forms and activities of the Bacteria, e.g. as to whether one form can give rise to progeny of another form when its food and conditions of growth are changed, and again, as to whether special fermentative powers can be lost or acquired in the course of generations derived from one parent germ, but subjected to different conditions as to food, temperature, and oxygen. The method of gelatine cultivation devised by Dr. Koch places the means of following out these inquiries in the hands of every careful microscopist. Such methods as Lister's were too troublesome and too difficult for general and widespread application; but now that monosporous cultivation of Bacteria has been rendered a comparatively simple and certain affair, we may expect immediate and immense advances in our knowledge of the whole series of phenomena to which the Bacteria are related.

"Amongst problems which require immediate investigation by the new method are the distinctive properties of the various kinds of Bacteria which may infest the wounds of surgical practice, and their specific susceptibility to the destructive influence of carbolic acid and other antiseptics; further, the possibility of isolating a specific Bacterium in contagious diseases not yet investigated; and (of great physiological interest) the isolation and investigation of the properties of the specific Bacterium of the ammoniacal fermentation of urine."

A remarkable negative result obtained by Dr. Koch, so far as his experiments with the new method of monosporous culture have yet extended, is, that there is no transition of forms amongst, at any rate, the pathogenous Bacteria—a Micrococcus produces Micrococci, and no other form; a Bacillus produces only Bacilli; a biscuit-shaped form (Bacterium proper) only biscuit-shaped forms; a Spirillum only Spirilla. Moreover, the *facies* of the discoidal or spherical mass formed by a growth, as seen with a low power, excavating its way in the gelatine, is characteristic of species, so that a practised observer can in some cases recognize a particular Bacillus or Micrococcus by the naked-eye appearance of the growth alone, or, at any rate, without actually observing the individual units of the growth.

Sterilization of Animal and Vegetable Liquids.*—Pasteur has proposed to render sterile liquids infested with Bacteria by filtration through plaster of Paris, and MM. P. Miquel and L. Benoist have devised a simple method for working out this process. The neck of a flask is drawn out, and the part above the contraction is sealed by a plug of plaster of Paris and asbestos, and immediately below the contraction a fine capillary tube is drawn out at the side. The apparatus is then dried for a week or two at 40° C., and finally heated to 170°, in order completely to destroy the germs on the sides of the flask and on the plug. When the flask is cooling, the capillary point is introduced under perfectly sterilized water, and on breaking it off, 40–50 c.c. of water pass up into the flask. The liquid is then boiled to expel the air completely from the flask, and the point is resealed, while at the same time the plug is introduced into the infested liquid. On cooling, the liquid passes into and fills the flask. The authors draw attention to various precautions which are necessary to ensure success.

Hardening the Spinal Cord.†—The following method of hardening the spinal cord for microscopic sections has been highly recommended by Dr. M. Debove:—

Place the cord in a 4 per cent. solution of bichromate of ammonia for three weeks, then in a solution of phenic gum for three days and for three days more in alcohol. Sections may then be cut with great facility. They should be placed in water to prevent curling. They are then immersed in a saturated solution of picric acid for

* Bull. Soc. Chim., xxxv. (1881) pp. 552–7. See Journ. Chem. Soc. (Abstr.), xl. (1881) p. 835.

† Archives de Neurologie. See Science, ii. (1881) p. 482.

twenty-four hours, and coloured with carmine for about twenty minutes, the picric acid acting as a mordant.

Transferring Sections from Alcohol to another fluid. * — In order to avoid shrinking in transferring from absolute alcohol into ethereal oil, or chloroform † (from a lighter into a denser fluid), Dr. W. Giesbrecht recommends that a quantity of absolute alcohol should be poured into a glass vessel, and by means of a pipette let the oil or chloroform run underneath it, so that the two fluids may lie one under the other; then drop the object into the alcohol, and take away all the superfluous alcohol. When the objects have sunk to the bottom of the vessel, the exchange of fluids is completed. Many objects, however, will not sink down in the dense chloroform; but this inconvenience can be got rid of by a suitable addition to the chloroform (e.g. sulphuric ether, &c.). In other cases the disappearance of those figures of refracted light, which always make their appearance when two fluids of different refractive powers mix, must serve to indicate the completion of the exchange. This is the most simple way to retard the exchange of fluids, and so avoid the cause of shrinking.

Imbedding in Paraffin and Freeing the Sections. ‡ — Dr. Giesbrecht also describes the process which he has found advantageous for imbedding the object after its transfer, as above described, from absolute alcohol into chloroform, which of all solvents of paraffin § gives the best results, and is most easily evaporated. Some sulphuric ether should be added to prevent the object swimming, and the chloroform, with the object, is then slowly warmed to the temperature of the melting-point of paraffin; whilst this is being done small pieces of paraffin are put in gradually. Here, too, shrinking is avoided, by making the displacement of the chloroform by the paraffin take place very gradually. It is completed when no more air-bubbles rise from the object.

For fixing the section with certainty and facility during the removal of the paraffin, a stock of slides should be provided, the centres of which are overlaid with a *very thin* and *very uniform* layer of shellac. Such a layer is easily produced by dipping a pretty thick glass rod into a well-filtered and not too concentrated solution of brown shellac in absolute alcohol, and passing it lengthways over a slide *previously warmed*. Shellac as clear as possible will of course be chosen; the so-called white shellac cannot, unfortunately, be used, because it is not soluble in alcohol. Before commencing cutting, brush over the shellac layer *very thinly* with creosote, ‖ and then lay the section upon it with *as little paraffin as possible*. The slide, with the section, is afterwards exposed for about a quarter of an hour in a water

* Zool. Anzeig., iv. (1881) pp. 483–4.

† This applies also to transfers from water or alcohol into glycerine.

‡ Loc. cit.

§ A solution of very hard paraffin in an equal volume of chloroform keeps fluid with the warmth of the hand.

‖ Creosote dissolves both shellac and paraffin, hence its application in this case. Turpentine does not dissolve shellac.

bath to the temperature of the melting-point of the paraffin used, and allowed to cool. The creosote is then evaporated, and the section fixed so well by the shellac that turpentine can be let pass over it freely without displacing it. After covering with Canada balsam, the shellac-layer is no longer discernible, provided it was thin and uniform.

Imbedding in Paraffin.*—Mr. E. L. Cheeseman, in cutting vegetable sections, makes a short paper tube the same size as the well-hole of the section cutter, by rolling a strip of paper round a cylinder; a cork is fitted to one end of the tube, and to the upper side of the cork is attached by cement or otherwise the specimen to be cut (previously hardened in alcohol, if necessary) in such a manner that it will stand upright in the centre of the tube. Fill the tube with melted paraffin, and when cold remove the paper, and there is a plug of paraffin enclosing the specimen. Several of these plugs should be made at a time, and kept in alcohol until wanted.

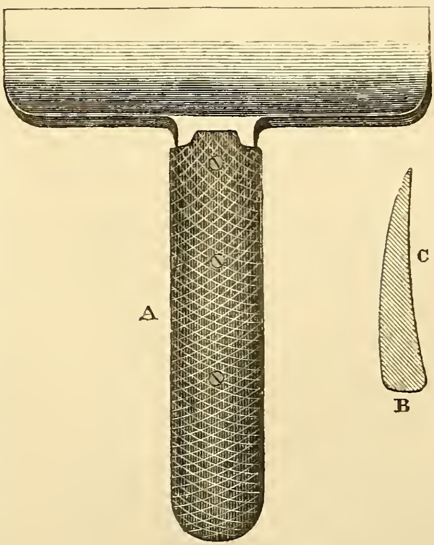
Taylor's Freezing Microtome.—At the last meeting of the American Association for the Advancement of Science, Mr. Thomas Taylor, Microscopist of the Department of Agriculture at Washington, presented a model of a new freezing microtome of his invention, which consists of a thin brass tube about $1\frac{1}{2}$ inch in length, by 1 inch in diameter, with a $\frac{1}{4}$-inch brass tube secured within the larger cylinder. This tube enters the bottom where it is secured, and proceeds to within a quarter of an inch of the inside surface of the top. To the outside open end of this tube a rubber tube is attached; the other end of the rubber tube is made to communicate with a freezing mixture composed of finely cut ice and salt in about equal proportions. The pail containing this mixture is placed over and about 15 inches higher than, the section-cutter. The object of this arrangement is to fill the brass cylinder with a freezing liquid, drained from the pail, and produced by the liquefying salt and ice, the temperature of which is about zero. On filling the cylinder with the liquid any object on the top of the cylinder becomes frozen in a short time, and may then be cut to any degree of thickness. In order to preserve the low degree of temperature in the cylinder, a second tube is secured in the cylinder to remove air and to keep up a constant current of the freezing liquid. This tube also enters the bottom of the cylinder, where it is fastened. It projects upward to within an eighth of an inch of the top, and has a diameter of about one-half of the supply tube. This microtome in other respects is arranged like the ordinary microtomes, used for ether or rhigoline.

Waller's Section-knife for large Sections.†—Dr. B. C. Waller recommends a knife, for service chiefly with the larger freezing microtomes, with wells 2 inches in diameter, and in making large sections. It consists (Fig. 226) of a blade $7\frac{1}{2}$ inches long, 2 inches broad, and $\frac{5}{16}$ of an inch in thickness at the back, set at right angles upon a stout

* Amer. Mon. Micr. Journ., ii. (1881) p. 114.
† Edinburgh Med. Journ., xxiv. pp. 893–5.

handle 10 inches long, formed by a prolongation of the metal of the blade, firmly riveted between two pieces of wood. It resembles a T, the horizontal part being the wood, and the vertical one the handle. The blade is thick and chisel-edged, to prevent bending into the well when pressed firmly upon the cutting-plate. When in use, the end of the handle is grasped by the right hand, while the little finger and adjacent palm of the open left hand are made to exercise steady pressure on the broad blade close to the handle. The breadth of the blade prevents the hand from coming into contact with the section when cut.

Fig. 226.



When a section is about to be made, the blade is placed in the ordinary manner upon that part of the cutting-plate nearest to the operator. The edge is then pressed firmly against the plane of the plate with the left hand, at an angle of about 45°, and the section shaved off by a rapid, steady, straightforward push of the edge through the tissue. By observing these directions the largest sections can be made with great rapidity, with perfect evenness, and with wonderful ease. In the figure, A is a general view, and B is the section of the blade, C being the edge which is held downwards in cutting.

It may be asked, If the section is made by a simple push or thrust, where is the necessity for a cutting edge $7\frac{1}{2}$ inches long? Why not use a broad knife at once? The reason for the extra length of blade is twofold: firstly, because, to prevent bending of the edge into the well, it is advisable to distribute the pressure upon those parts of the cutting-plate which lie to each side of it; and secondly, because for certain tissues a drawing, or rather an oblique pushing cut, is preferable to a straight thrust, and for such a method of cutting a considerable length of edge is requisite. In cutting nervous tissues, the knife should be slowly pushed through with a steady equable pressure, when, if properly hardened, they will curl themselves up on the back of the knife, and may then be transferred to a basin of water in the ordinary manner.

The author claims that by this knife large and perfect sections can be cut to almost any degree of thinness, with greater facility, rapidity, and certainty than with the ordinary pattern. The difficulty in keeping the edge flat in the cutting-plate is entirely obviated, as the downward pressure is exercised with the whole left hand, instead of with the tips of the finger and thumb.

Staining of Living Unicellular Organisms.*—K. Brandt finds hæmatoxylin and Bismarck-brown suitable colouring materials with which to stain Protozoa in the living state. For Amœbæ and Heliozoa a dilute solution of hæmatoxylin in water is allowed to act for a short time; in any case the process must be limited to an hour, as even Amœbæ succumb to a longer treatment. Pure water should then be allowed to replace the staining fluid. The nuclei are found stained pale violet. By this method the author has discovered nuclein in the form of numerous round granules in the endosarc of Amœbæ and *Proteus*, Leidy, measuring from $\frac{1}{1500}$ to $\frac{3}{1000}$ mm. in diameter; they have the same optical properties as the nuclei, and react chemically in the same way, and stain readily and deeply with hæmatoxylin. The bulk of extra-nuclear nuclein may be seen in old specimens to exceed that of the nucleus itself, and in young individuals exclusively to represent the nucleus. The author has been led by the remarkable appearance of the so-called nuclei to regard them as reproductive bodies, and to consider the nuclein granules as representing the nucleus proper, for the membrane enveloping the nuclei appears in this *Amœba* to consist of cellulose, it being insoluble in solution of caustic soda, but dissolving in ammonia-oxide of copper.

Hæmatoxylin at first produces no visible change in the liquid of the contractile vacuole; this later assumes a yellowish tint, and finally becomes brown shortly before death: the acid reaction of the liquid is thus proved. Bismarck-brown stains the nuclei of dead cells, but the only parts of Protozoa affected by it in the living state are the fatty granules and a peculiar mucous substance resembling cellulose. The solution should have a strength of either 1 to 3000 or 1 to 5000; it is best adapted for Heliozoa, Amœbæ, and Flagellata, which remain quite healthy even after staining for several hours, and when the parts above-mentioned have assumed a deep brown, if replaced in pure water; the colour is long retained by the fat-granules. Double-staining may be effected by first using Bismarck-brown for an hour, and then hæmatoxylin for a much shorter time; the protoplasm alone remains uncoloured. The difference in their colours shows which of the granules are fatty and which consist of nuclein. When death sets in, in consequence of this treatment, the nucleus becomes very deeply stained, and the protoplasm acquires some colour. The action of cyanine or quinolein blue, used in the proportion of 1 : 100,000 or 1 : 500,000, recommended by Certes for Infusoria and histological elements,† is essentially the same as that of Bismarck-brown. Certes finds that Infusoria also stain with Bismarck-brown.

Klein's Cochineal Fluid.‡—Dr. R. J. Harvey recently exhibited to the Dublin Microscopical Club specimens of cerebellar cortex,

* Biolog. Centralblatt, i. (1881) pp. 202–11.
† See *ante*, pp. 527 and 694.
‡ Ann. and Mag. Nat. Hist., viii. (1881) p. 232.

cerebral cortex, and gastric mucous membrane, stained with Klein's cochineal fluid. The preparation of and *modus operandi* with this fluid are exceedingly simple: 1 per cent. of alum and cochineal in distilled water are boiled to four-sevenths of the original volume; when cool, a few drops of carbolic acid are added, and the liquid filtered. Sections will stain well in three or four hours, but will not be injured if left twenty-four hours. They require nothing but washing in distilled water. The branching processes of Purkinje's cells in the cerebellum, the connection of the kite-shaped cells of the cerebral cortex, and the "chief" and "investing" cells of the gastric mucous membrane were rendered especially evident by this method.

Purpurine for Staining Fœtal Vertebræ.* — Dr. Harvey also showed a section of fœtal vertebræ stained with purpurine. All the effects for which double-staining had been so much recommended of late, in studying the process of ossification in cartilage, are brought out by this dye. The cartilage matrix remains unstained, the new territories of bone-substance assume a distinct though somewhat pale hue, while all the cells (cartilage-cells, bone-cells, osteoblasts, and marrow-cells) become brilliantly stained.

Cements and Cementing.†—Mr. C. E. Hanaman, after an experience of more than twelve years, during which he has used nearly every kind of cement that has been suggested in the journals and books published in England and America, has arrived at the conclusion that two, or at most three, cements are capable of ensuring the preservation of an object in any medium the microscopist will find it necessary to employ. These are gold-size (Windsor and Newton's), the ordinary dammar mounting medium, and possibly, for occasional use, the dammar medium to which a small proportion of a solution of rubber in naphtha has been added.

Dr. Seiler and others have directed the student to apply his cements in several coats, using great care in holding the brush, and as to the quantity of cement in the brush. The author saves himself much of the time required by such methods of manipulation, by putting on the cement in a broad band over the junction of the cover with the slide, and then, spinning the turntable as rapidly as possible, running the cement into a narrow band, in its proper place, by holding a knife-blade first on the slide and then on the cover, in such a manner as to cause the cement spread out by the brush to heap itself up into a narrow but perfect ring. One coating of cement thus put on is equal to three or four coats by the other method, while the polish of the ring far surpasses in perfection the brush-made ring.

If it is desired to colour the ring, instead of using anilin mixed with the cement, the more transparent of the water-colours are useful. The manner of their application is this: After the dried balsam or dammar has been thoroughly cleaned from the slide and cover, the preparation is placed on the turntable, and a narrow ring of the water-colour applied. This will dry quickly and look somewhat

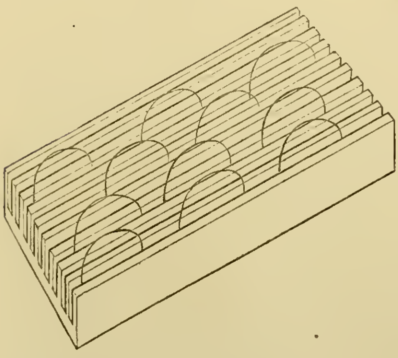
* Ann. and Mag. Nat. Hist., viii. (1881) p. 234.
† Amer. Mon. Micr. Journ., ii. (1881) pp. 143–4.

opaque. The dammar cement is then put on over the coloured ring as above directed, and it will be found that the result is equal in beauty to the celebrated shellac and anilin rings of Mr. Merriman, without the danger of the colours running in, as they often will do when anilin or any colour soluble in the cement is used. When glycerine or aqueous fluids are used, it is necessary to apply the dammar alone for a first coat, the water-colour being applied over this, and a final coat of gold-size or rubber cement over all. Windsor and Newton put up water-colours in little vials ready for use, under the name of "liquid water-colours," by the use of which the student may save himself the trouble of rubbing down the cake.

The centering of the cover may be quickly and accurately accomplished in the following manner:—The slide is placed in the jaws of the self-centering turntable, a very narrow ring of water-colour is made upon its surface with a finely pointed brush exactly the size of the cover-glass to be used. This will dry very quickly; if a number of slides are done at one time, the first will be dry by the time the third is done. The coloured ring being insoluble in any but water mediums, the object may be arranged on the slide in alcohol, oil of cloves, carbolic acid, balsam, or dammar, and it will be easy to see when the edge of the cover exactly coincides with the edge of the coloured ring. This ring will show through the transparent ring used for finishing, provided it be not covered by a broader ring of colour before the finishing ring of cement is applied, as suggested above. In any case it does not detract from the appearance of the slide.

From the fact that the glass slides are not perfect rectangles, it is necessary to place the same corners in the same clutches of the self-centering turntable every time a slide is manipulated on the table. The simplest way to do this is to mark one of the clutches with a cross, and similarly to mark with a file or writing diamond one corner of each slide while cleaning it.

Fig. 227.



Preserving Cover-glasses.*—Mr. C. E. Hanaman keeps upon his work-table one or more grooved blocks like that shown in Fig. 227, in which cover-glasses that have been selected for immediate use are supported on their edges, and from which they can be easily taken by the forceps.

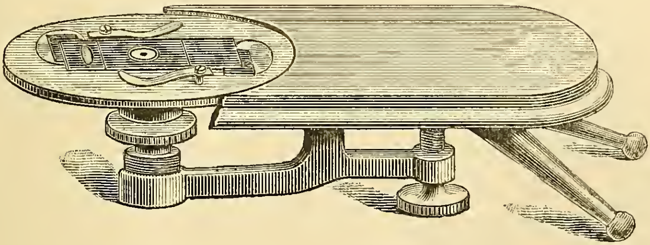
It is also convenient, when a number of covers have been cleaned, to keep them in drawers or boxes filled with narrow strips of new

* Amer. Mon. Micr. Journ., ii. (1881) pp. 142–3 (2 figs.).

white blotting-paper, between which the covers are placed on edge. This not only preserves them from breakage, and enables one to readily pick them out when wanted for use, but also facilitates the selection for special preparations of those of the most desirable thickness; for, by holding the drawer or box between the eye and the light, it is easy by comparison to select the thickest or thinnest cover, and thus, for all practical purposes, to do away with the trouble of measuring them.

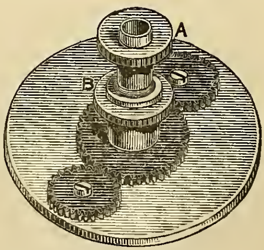
Sidle's "Congress" Turntable.—This turntable (so called from having been first exhibited at the "Congress of Microscopists" at Indianapolis) is shown in Figs. 228 and 229.

FIG. 228.



Into the upper surface of the rotating plate, and diametrically opposite and equidistant from the centre, are set two circular plates or disks, 1 inch in diameter, their surfaces flush with that of the large plate. Pivots from the two disks project through the plate, and each carries upon the lower side of the plate a toothed wheel. A hollow sleeve rotating freely upon the stem of the table carries a third and larger wheel, which gears into the two others and thereby gives rotation to the disks in the top of the plate. In Fig. 229 the turntable is inverted to show the mechanism.

FIG. 229.



Near the opposite edges of the two disks, the angular jaws which hold opposite corners of the slide are pivoted (as in Cox's and other forms), so that by giving rotation to the central wheel under the plate, the jaws may be made to approach or recede at pleasure.

A coiled steel spring, concealed within the hollow sleeve, serves to close the jaws, while a single motion of the milled head B, Fig. 229, upon the sleeve, opens them to their full extent; the lower milled edge A serves to give rotation to the turntable.

Although the jaws do not approach in a straight line, yet when properly adjusted, a line joining the pivots of the jaws will cut the centre of the plate, whatever the position of the jaws, and they being always equidistant from the centre, it follows that the slide, when clasped between them, must be perfectly centered. For the purpose of retouching old slides the ordinary spring clips are retained.

An improvement has been made in the supporting stand, the iron tripod being now so arranged that the hind legs are removable and, being held in position by a clamp-screw, the same screw serves to clamp the instrument upon the edge of the work-table, should this mode of using it be preferred.

New Process for Preparing the Brain.*—In place of nitric acid, chloride of zinc or chloral, a new process is described by which the brain is plunged in a saturated solution of bichromate of potass in a vessel large enough to admit of complete submersion, or if it be wanted for histological studies, susceptible of being cut in small slices for microscopical examination, bichromate of ammonia should be substituted for bichromate of potass. The brain should remain immersed a fortnight or longer; it will then be much swollen, and the infiltration will be completed. It is then taken out of the bath and plunged into simple water, in order to expel any excess of the bichromate. It is then placed in a bath of carbolic acid, 25 grammes to 1000 grammes. This process has the property of hardening the brain-substance, and reducing it almost to its normal size. A little acid must be added from time to time in order to keep up its hardening effect, which is apt to lessen. Six to ten days will suffice for its remaining in the acid bath.

As soon as the brain is taken out of the carbolic acid bath, it is plunged into a bath of pure glycerine for three or four days; the specimen may be wrapped in a cloth so as to prevent any part of the brain from emerging from the ambient liquid. It should not be left longer in the glycerine, for the brain absorbs a very large quantity of it, which might interfere with the hardening process. The brain is then taken out, placed on the flat side on soft linen, and exposed to the air. Should there be an excess of glycerine, plunge it for eight to ten minutes in a water bath. It is left now to itself, and will assume a green bronze colour, dry, and mummify almost insensibly. In two or three weeks the desiccative process will be completed. The specimens can be kept in open air or in boxes.

This process of preserving the brain, though seemingly complicated, is in reality very simple, if once the habit of using it be acquired. Such brains have now been in the laboratory for two years and a half, completely imputrescible, and have lost only three-tenths of their original value. They are susceptible of being freely sliced for histological investigation.

Action of Concentrated Osmic Acid on Bone-cells.†—M. F. Tourneux has studied the exact form and intimate relations of the osteoblast by the combined action of impregnation of the tissue with concentrated osmic acid, and decalcification by the aid of formic acid

* Lond. Med. Rec., Aug. 15, 1881, pp. 308-9.
† Bull. Sci. Dép. Nord, iv. (1881) pp. 113-15.

(2 to 3 per cent.); if the fragment of bone thus treated be only a few millimetres thick (rat, guinea-pig), twenty-four to forty-eight hours is sufficient to soften it; thicker pieces may require decalcification for a week. After washing, sections were then made, and these were mounted in glycerine. The osteoblasts are now seen as "true excavations" filled with liquid; fine prolongations become observable, and the primitive bone-cell is found to have been pushed to the wall of the osteoblast, owing to the development of a liquid between it and the osseous matter, and to have carried its prolongations into the neighbouring canaliculi. When a series of young forms are studied one can see spherical vacuoles developed in the interior of the osteoblast. The author explains that this appearance is not due to the production of a gas by the action of the formic acid, as it is seen when such reagents as picric or chromic acids are used instead.

Mounting Chick Embryos whole.* — Dr. C. S. Minot recommends the following method for embryos under forty hours. The egg is opened in the usual manner in warm 0·5 per cent. salt solution, the blastoderm freed from the yolk membrane, then swayed with pincers to and fro in the liquid to remove the superfluous yolk, and then floated out on a glass slide on which it is to remain permanently. It is next treated with several fluids, *all* of which should be dropped on the centre of the germ disk, so as to spread out the blastoderm evenly by their centrifugal flow. Wash off thoroughly with distilled water. Remove the water as fully as possible by bibulous paper, and allow the specimen to remain fully spread out until the edges are dried. The embryo will then escape distortion during the further treatment. Care must be taken that the embryonic area remains moist. Drop on two drops of a ½ per cent. osmic acid solution: leave standing for two or three minutes until a slight browning is produced, wash off again with distilled water, stain with picro-carmine, which dyes the blastoderm after a variable time, according to the intensity of the osmic acid action. The next step is important, because it stops the further darkening by the osmium, which otherwise injures or ruins the specimen. Pour Müller's fluid, or 0·5 per cent. chromic acid solution, on the slide, and leave it overnight. The next morning the blastoderm is ready for dehydration by alcohol, and mounting in the usual manner in balsam, or better, in three parts pure Canada balsam mixed with one part dammar varnish.

Embryos mounted in this way make very perfect preparations, surpassing, indeed, those otherwise treated.

Mounting Echinoderm-larvæ. — The following mode of preparing and mounting Echinoderm-larvæ has been communicated to Dr. Carpenter † by Mr. Percy Sladen who mounted the slides which attracted much attention on the Scientific Evening of 3rd December, 1879 (see Vol. III. (1880) p. 375). "For killing and preserving Echinoderm-zooids I have come to prefer either osmic acid or the

* Amer. Natural., xv. (1881) pp. 841–2.

† 'The Microscope and its Revelations,' 6th ed., 1881, pp. 646–7.

picro-sulphuric mixture of Kleinenberg of one-third strength. The latter, of course, destroys all calcareous structures; but the soft parts are preserved in a wonderful manner. If the diluted Kleinenberg's mixture is used, let the zooids remain in it for one or two hours; then wash them thoroughly in 70 per cent. spirit, until all trace of acid is removed; then strain; then again wash in 70 per cent. spirit, transfer them to 90 per cent. spirit for some hours, and lastly to absolute alcohol; transfer them from this to oil of cloves; and finally, mount in Canada balsam in the usual manner. If osmic acid be used, place three or four of the living zooids in a watch-glass of sea-water, and add a drop of the 1 per cent. solution. They should not remain even in this weak solution for more than a minute, and should then be thoroughly washed in a superabundance of 35 per cent. spirit, to prevent the deposit of crystals of salt consequent on the action of the osmic acid; then transfer the specimens to 70 per cent. spirit, and proceed as in the other case."

Mounting Class.—The Manchester Microscopical Society have adopted the excellent idea of establishing a class for affording beginners instruction in dissecting and mounting of objects, the work being superintended and practically illustrated by several of the more experienced members.*

Mode of detecting Adulterations in Flour by the Microscope.†—A. Cattaneo publishes two tables, with illustrative text, giving a detailed account of the anatomical differences in meals and in wheat, and of the adulterations of wheatmeal with the meal of rye, barley, maize, rice, oat, and millet, the latter of which, however, rarely occur. Besides other cereals, the flour is also adulterated with that of leguminous plants, and others containing abundance of starch, as the potato, horse-chestnut, Spanish chestnut, lupin, vetch, pea, lentil, haricot, &c. A comparative description of the starch-grains of these various substances is given.

Reagent for small Quantities of Oxygen from Living Organisms.‡—T. W. Engelmann claims to have discovered a reagent by which the evolution of oxygen can be detected in any microscopic organism, as, for example, a single chlorophyll-grain; and, within certain limits, even the amount of oxygen evolved be determined. The sensitiveness of the reagent is so great that far less than the hundred-billionth part of a milligram can be detected with certainty. It acts also so quickly that sudden changes in the amount of oxygen given off are indicated momentarily without loss of time. The reagent is any of the ordinary bacteria of putrefaction, especially the smaller forms, *Bacterium termo*.

It is well known that these bacteria are, in their motile condition, dependent to an extraordinary degree on the presence of oxygen,

* See Report of closing meeting for the first year, North. Microscopist, i. (1881) p. 245.

† Rend. R. Ist. Lomb. Sci. e Lett. xiv. See Bot. Centralbl. vii. (1881) p. 173.

‡ Bot. Ztg., xxxix. (1881) pp. 441–8.

collecting in enormous quantities, and moving about with great rapidity wherever they come into contact with the air, and losing their motility the moment this is removed. Exposed to a stream of pure hydrogen they soon subside completely to rest; pure oxygen acts with greater energy than the atmospheric air.

If a drop of defibrinated blood, which has been oxygenated by shaking in the air, is run into a drop of water between two glasses in which all bacteria have come to rest, they begin at once again to move about actively at the point of contact of the two fluids. This does not take place (or at least only at a very few points, and for a very short time), if, instead of arterial blood, that is taken through which a stream of carbonic oxide has been passed immediately before. If, instead of the drop of oxygenated blood, green cells, such as *Euglena*, a piece of a filamentous alga, or a brown diatom like *Navicula*, are brought into contact with the drop containing motionless bacteria, and observed under a cover-glass with a magnifying power of 200–300, the bacteria are seen immediately to begin to swarm in great quantities about these cells, while in all other parts of the drop they are completely at rest. If the field of view is now suddenly darkened, but not so much as to prevent the bacteria from being still distinctly visible, the swarming bacteria at once come to rest, either remaining stationary at the same spot, or dispersing themselves through the fluid by molecular motion. When the light is again let in, the motion recommences.

The only satisfactory explanation of these phenomena is that the chlorophyllaceous cells give out oxygen under the influence of light, and that this is the cause of the movements of the bacteria, and of their collecting round the spot where it is given off.

The following are some of the results of the application of this test obtained by Engelmann.

All chlorophyllaceous cells of both lower and higher plants give off oxygen in the light, even when the ordinary green colour is replaced by brown, as in diatoms, or by olive-green or light green, as in many Flagellatæ and Oscillatorieæ. The same is the case with chlorophyllaceous animals, as *Paramecium bursaria*, *Hydra viridis*, and *Spongilla*, sometimes very energetically.

The parenchymatous cells of the leaf of seedlings of *Nasturtium* grown in the dark, which contain etiolin but no chlorophyll, when brought into moderately strong light, momentarily exhale oxygen. But after exposure to the light for an hour at a uniform temperature of 21° C., the yellow colour of the cells was not sensibly altered.

The energy of the evolution of oxygen in different kinds of cells is greater the larger the amount of chlorophyll, or of other colouring matter with the same physiological properties. It is, for example, very great in *Euglena viridis*, or in young cells of *Zygnema*; small in cells of *Spirogyra* where the chlorophyll-bands are narrow and some distance apart, and in the guard-cells of the stomata of the leaf of *Tradescantia*. No evolution of oxygen takes place from cells with colourless protoplasm, as monads, amœbæ, the mycelial filaments of moulds, the root-hairs of *Hydrocharis*, the colourless cells of the parenchyma of albinotized maple-leaves, &c., or from any non-chlorophyllaceous animal cells. Cells with a coloured cell-sap, but no chlorophyll, as those of the hairs on the filaments of *Tradescantia virginica*, petals, &c., do not give off oxygen into the air.

In all living cells, the evolution of oxygen takes place only at those spots where the chlorophyll-grains lie; and this is the case even when the chlorophyll-bodies have retreated from the cell-wall. Completely isolated chlorophyll-bodies of not more than 5 μ diameter continue to give off oxygen, as may be plainly seen in *Hydra viridis* and in many plant cells. The evolution proceeds even when the surrounding protoplasm has been completely destroyed. Even when a part of the chlorophyll-body has been destroyed, the remaining portion continues to act; but, as soon as its structure has been completely destroyed, the power of giving off oxygen ceases. The evolution is independent of currents in the protoplasm. Electrical induction-currents, which caused contraction in *Euglena*, produced no change in the evolution of oxygen.

The phenomenon takes place at all periods of growth and of cell-division; the nucleus appears to have no influence upon it. It seems to be absolutely dependent directly on the influence of light. The ultra-red rays passed through a solution of iodine in bisulphide of carbon, were found to be completely inactive; while the red rays of a wave-length between 0·70 and 0·60 μ were very active; the orange and yellow still more so; the green rays were the weakest; the blue (below 0·50 μ) often considerably stronger. There is no perceptible interval of time between the impact of the light and the commencement of the development of oxygen; and the latter appears to cease the moment the former is withdrawn.

Micro-photography.*—At the Brieg meeting of the Swiss Natural History Society, Dr. Du Plessis exhibited some micro-photographs of Hydroids—negatives on glass for projection—at the same time lamenting that the numerous technical difficulties produced disappointments which discouraged naturalists, although micro-photographs were of extreme importance both on account of their faithfulness and their usefulness for class instruction. M. His, however, contended that the discouragement arose primarily from the fact that proper objects were not selected, all microscopical objects not being suitable for photographing. The most unfavourable objects were often first selected, and there was always a temptation to employ too high powers. Only those objects should be used which can be observed with low powers, and especially those which give stereoscopic images.

Histology and Microscopy.—Microscopists have for many years insisted that it is absolutely essential that histologists should be grounded in the theoretical principles applicable to the instrument with which they work, and, that if this is not done, not only will erroneous interpretations of structure be put forward, but many points of importance will be altogether missed.

* Verh. Schweiz. Naturf. Gesell., lxiii. (1881) pp. 39–41.

In England, this view has not been accepted in practice, and an histologist who attempted to determine the true structure of an object by experimental or theoretical optical considerations was a *rarissima avis* indeed.

A very curious illustration of the mistakes that must inevitably result from this neglect will be found in a paper which has recently appeared by Mr. J. B. Haycraft "Upon the Cause of the Striation of Voluntary Muscular Tissue," * in which the author, with much care and ingenuity, reproduces the twice reproduced view of Mr. Bowman, that the striation of muscular tissue is simply an optical effect caused by the undulating shape of the fibres.

The paper evidently commended itself to histologists of eminence, as it was printed at length in the 'Proceedings of the Royal Society,' and reprinted in the 'Quarterly Journal of Microscopical Science,' and so far microscopists may congratulate themselves upon the acceptance in principle of a point on which they have hitherto vainly endeavoured to make themselves heard; but the paper points a still further moral in regard to the importance of a knowledge of the theory of microscopical appearances, for the author (who describes his paper as an attempt to explain the structure of muscle "on simple laws of geometrical optics") was unaware that, as established by Professor Abbe, there is a limit beyond which the laws of geometrical optics have no application, and that it is useless to attempt to reason as to the appearances presented by an object which requires a power of 500 times from those presented by one which requires a power of only 50 times. The laws of refraction in particular, for instance, no longer holding good in the case of minute objects, and cylindrical threads entirely losing the characters of refracting bodies which are distinctly exhibited by similar objects of larger size.

Whilst, therefore, the author is worthy of every commendation for his adoption of a method hitherto too generally neglected, the basis on which he rests his conclusions is unsound in consequence of the error into which he fell at starting.

We subjoin some extracts from Mr. Haycraft's paper which will, we think, be of interest to microscopists:—

"We can account for all these cross markings in a way which involves no theory, and requires for its appreciation but a knowledge of most elementary geometrical optics. If a small fragment of muscle be teazed out in water, salt solution, or almost any other fluid, and examined in the ordinary way, with a power of 300 diameters or more, the important fact may be made out (which is the basis of all my future observations) that the borders of the fibres are not smooth, but undulate, presenting wavy margins.

"In the fresh, unstained preparation there is a halo around the edge of the fibre which masks the crenulated border, yet by carefully adjusting the mirror so as to obtain oblique light, or by searching for a fibre partly in the shade of another, this may always be made out; in the case of insects' muscle, this is, however, always easy to demonstrate, for the fibres are much coarser, indeed, the appearance has

* Proc. Roy. Soc., xxxi. (1881) pp. 360–79 (1 pl.).

been often figured in the works even of recent histologists. If the preparation be stained by any of the ordinary dyes, perhaps most readily by picro-carmine, the border is in all cases very distinct, and the regularly sinuous margin is unmistakable. Now, what is the significance of the wavy outline? It is, as will readily be understood, that the fibre is ampullated, the wavy outline being but the optical expression of such a figure. A muscular fibre is then not a smooth cylinder, but is like the turned leg of a chair, or like the transversely ribbed neck of a common water-bottle in shape. If the fibre be broken up into fibrillæ, which is very easy after maceration in alcohol, these are seen to have just the same characters, indeed, a small bundle of fibrils is most convenient for study. It may be well to remark, that the ultimate fibrillæ often show but little cross markings, and appear almost smooth; that is, however, only due to their small size; a good lens will bring out both points. . . .

"The transverse stripings of the fibre are related to and correspond with the inequalities of the surface. The little elevations at the borders correspond, of course, to the little ridges, which run round the fibre, while the dips at the borders are the optical expressions of little valleys running between them. In the ordinary position, the dark stripe marks the position of the ridge, and the light stripe lies in the little valleys.

"Then, again, Dobie's line (Krause's membrane), which is a faint dark band in the very centre of the bright stripe, runs along the bottom of the valleys, and Hensen's stripe in the centre of the dark band, lies on the exact summit of the ridges.

"This position of the stripes in a normal muscular fibre, is the invariable rule, and the idea at once suggested itself, may not the shape of the fibre itself cause the cross stripings?

"Any student of natural philosophy would at once affirm that a structureless fibre of such a shape must be cross striped, and a glance at the ribbed neck of the water-bottle on the table will elicit the same answer from any one.

"The question we must now determine is, are the appearances seen in the fibre just the same, in all their details, as would be produced by a piece of glass, or any other homogeneous transparent substance of the same shape?

"Before, however, entering into theoretical grounds, it may be as well to give a full description of what is actually to be seen, for this has not yet been stated.

"With a structure of complicated figure, such as the one we are considering, it is obvious that there is no one focus in which it may be described. There is one pretty definite focus for a single speck or thin film, but even when examining a simple cylinder, it is evident that when the borders of it are clear and distinct, the upper surface is slightly out of focus. We shall see, that in the case of the muscle, although there is one position of the lens when the parts are very distinctly seen, and in which they have mostly been described, yet that on slightly altering the focus, the appearance is changed. These changes we must carefully study.

"For this purpose we may select the large muscles of the thigh of a rabbit; stretch them ever so little upon a piece of wood, and place them for some days in 50 per cent. alcohol. A high power is required for their examination. I have been in the habit of using a $\frac{1}{24}$-inch of Gundlach, a very perfect lens; a $\frac{1}{10}$-inch will, however, do. A small bundle of fibrils should be selected in preference to a whole fibre for examination.

"On focussing, it becomes at once apparent that on varying the adjustment ever so little, you may bring into focus the tops of the ridges or the bottoms of the valleys which lie between them. Now this slight alteration is sufficient entirely to change the optical appearances.

"First raise the lens until the fibre be out of focus, and is only to be seen as a dim streak running across the field, then bring it down until its form and the cross markings are distinctly to be seen (the border is now not quite distinct, on a level with the horizontal axis of the fibre). In this position, alternating light and dark bands are made out, but no vestiges of Hensen's stripes or Dobie's lines. The dark band corresponds with the valley and the light one to the ridge, or crest. . . . If the lens be now lowered ever so little, the stripes are reversed, a most curious point, which was noticed by Bowman, but afterwards lost sight of. The dark band now corresponds with the ridge, and the bright band with the valley. This is the focussing in which it is usually described, and in this position Dobie's line and Hensen's stripe are to be seen, as a rule, in uncontracted fibres.

"Between these two positions of the lens there is generally a well-marked intermediate one. The crests and valleys are both bright, and equally so, although the slightest movement of the fine adjuster will make either one or the other the darker; on the slopes, as it were, there are, however, narrow shaded bands. The fibre is now quite clear and distinct, and the longitudinal fibrillation is now best made out—if it can be seen at all—and yet there is no sign of either Hensen's or Dobie's stripes. These being the observed appearances (and they may be verified without very much trouble), I shall calculate theoretically the appearances which a homogeneous fibre of such a shape should present when examined by transmitted light, so as to see whether our observed effects tally with what may be theoretically calculated.

"Parallel rays of light pass upward through the fibre, and in their course are altered in direction. The substance of the fibre being of higher refrangibility than the fluid in which it is mounted, the thicker parts which correspond to the ridges will act like converging lenses, causing the rays of light to come to a focus, diverging again. The thinner parts (the valleys) will, on the other hand, act as diverging lenses, causing the rays to spread out. Now it is evident that when the objective is arranged to focus those rays which have passed through the fibre and converge over the ridges, at that same position the rays above the valleys will be diverging. This will produce a difference in the appearance, for the converging rays will give a bright band, while the position of those rays which diverge will appear darker. Alter the focus by screwing the lens up or down, and, provided the fibre can still be seen, this state of matters will be reversed; for after converging, the rays above the position of the ridges will now be diverging, while at the same time those over the valleys will be converging and will appear bright.

"The condition which is intermediate between the low and high focussed picture of the fibre, would be obtained by shifting the lens half-way between these two positions. Hensen's stripe is no doubt due to rays passing through the centre of the ridges suffering little refraction in their course, and thus causing a brightness. Dobie's line might, of course, be the reverse of this, no rays at this point coming to the eye of the observer; but we shall speak of this more hereafter, when we shall show that there is some reason for suspecting at this point a distinct structure.

"Although it is indispensable to account theoretically for these appearances, yet to most persons a simple demonstration will carry more conviction than any proof deduced from the laws of optics, however well they be understood. Instead of showing 'what should be,' we will study 'what is.'

"For this purpose we will imitate as nearly as possible the figure of a muscular fibre on a small scale, and it shall be made out of a substance of uniform consistence throughout. What appearances will it present on microscopic examination? I have proceeded in the following manner:—A glass rod is heated in a spirit lamp and plunged into a bottle of Canada balsam; it is then withdrawn, and a little drop of the balsam is allowed to fall on a glass slide, or a thread of it may be laid out on the surface of the glass. Before the drop or thread has solidified it is indented with the milled head of a fine screw, and examined with a power of from twenty to fifty diameters, when cross shadings are to be observed. These are seen, moreover, to correspond with the surface impressions, and not only so, but they are reversed on altering the focus. Hensen's stripe is generally very well seen. The most beautiful and convincing object to study in this connection is a scale of the *Lepisma*. These are sold as test objects with many Microscopes. They are oval in shape, transparent, and singly refractile throughout, and beautifully ribbed in their length, these ribbings or groovings being indeed so fine that a power of at least 500 diameters will be required to make out those points to be here described. You would think on looking at one of these scales that a piece of muscle was flattened out before you on the field: no rough balsam model, but a perfect illustration taken from the back of a tiny insect.

"The appearances it is needless to describe, for they are, almost to the minutest detail, those of a muscular fibre. The bright and dark stripe interchanging with every alteration of focus, Hensen's stripe and Dobie's line (Krause's membrane) are all to be seen. In the case of *Lepisma* scale the line of Dobie is in the centre of a bright band, which is broader than the dark band with Hensen's stripe. This is, of course, the other way in the case of the muscular fibre.

"We see, therefore, that a muscular fibre presents just those appearances which a transparent body of uniform texture and of similar shape would possess. However conclusive these proofs may have been, it is well to collect all evidence possible to show that these markings are nothing more than optical effects, to which end a very searching experiment was suggested to me by Professor Tait. It is evident that if these cross bands are seen when parallel, or nearly parallel, rays of light are passing through the fibre, by using converging or diverging rays the appearance will be altered, and it will be possible by careful adjustment of a lens to cause a total reversal of the striping. If a fibre be carefully focussed, and a strong bi-concave diverging lens be placed between the stage of the Microscope and the mirror, and carefully moved about with the fingers, it will be possible entirely to alter the fibre, causing a total reversal of the cross bands. On withdrawing the lens, of course the fibre resumes its normal appearance. I may mention that several lenses were tried before one was found which would in at all a satisfactory manner show this phenomenon; when successful the experiment is very striking.

"In opposition to my view is the one generally accepted, namely, that the cross stripings are produced by differences along the fibre of chemical composition and refrangibility.

"Now suppose that there were along the fibre two alternating structures, A and B. Let A represent the bright stripe, and B the dark stripe. If A has a higher or lower refractive index than B, it is evident that although they were immersed in any number of fluids of refrangibility varying from the lowest to the highest, yet A would always be distinguishable from B, and the striping would always be apparent. Then, again, by placing the fibres in fluids of indices near to that either of A or B, the more striking would be the contrast. If, however, the fibre were homogeneous throughout, the striping being merely due to the form, then if the fluid and the fibre have the same refractive index, all striping will disappear. On Professor Tait's suggestions, I tried a series of fluids formed by mixing, in various proportions, alcohol, whose refractive index is low, with oil of cassia, which is high. In this way I have prepared specimens showing almost no cross striæ, the fibre appearing uniform until after most careful examination. . . .

"The position that we have reached is this: a muscular fibre presents such cross markings, varying with shifting the lens up or down, as a filament of homogeneous structure and similar shape. I have shown this experimentally, and have illustrated it by simple experiments, which it is in the power of any one to test. This being the case, I have searched to find if there be reason to assert any want of uniformity along the fibre, using various methods of staining. This I have failed to do, and have shown that the views commonly held are to be explained simply by the shapes of the fibres. . . .

"A fibril is structureless throughout its entire length, except that, perhaps, there may be membranes, or lines of fission, or layers of cement at the positions of the lines of Dobie; this we leave an open question. In using the word 'structureless,' I must not be misunderstood; structureless membranes and tissues are fast losing their place in histology, and once simple protoplasm is now most complex. What I infer is that the stripes do not mark the positions of alternating layers of different structure, the presence of which are ordinarily maintained."

[We do not, of course, intend to express any opinion as to the real nature of muscular striation, our object being to recall the fact that the appearances presented by muscular fibre are not phenomena of geometrical optics and cannot be explained, nor the problems to which they give rise settled, on "simple laws of geometrical optics," a fact which is readily tested by experiments which it is in the power of any one to make.

If a piece of muscular fibre, which shows the striation well, is observed with a narrow incident pencil of direct or oblique light, and the eye-piece removed, a row of diffraction spectra will be seen at the back of the objective. If all these are shut off by a suitable diaphragm as in the well-known experiment, all striation disappears, or if some only are admitted—in varying combinations—a great variety of entirely different appearances will be obtained from the same fibre.

Whether, therefore, the phenomena of striation are due to the internal structure of the fibre or not, they are not phenomena of geometrical optics, which can of course tell us nothing as to optical images which depend on the admission or non-admission of diffracted light.]

Microscopy in 1830-1881.—Amongst the multiplicity of subjects to be dealt with, microscopy could be accorded but a brief reference in the Presidential Address at the York Jubilee Meeting of the British Association, confined to the question of the visibility of atoms, Sir John Lubbock stating that "we cannot, it would seem at present, hope for any increase of our knowledge of atoms by any improvement in the Microscope. . . . Even . . . . if we could construct Microscopes far more powerful than any we now possess, they would not enable us to obtain by direct vision any idea of the ultimate molecules of matter; . . . there may be an almost infinite number of structural characters in organic tissues which we can at present foresee no mode of examining."

It will not now be many years before this Society will have to celebrate its Jubilee, when the progress made in the mechanical, and still more in the optical arrangements of the Microscope, during the fifty years of the Society's existence, will no doubt be enlarged upon either in the Presidential Address or otherwise.

Obituary. M. Nachet, Sen., and Mr. C. A. Spencer.—We have to record the death of M. C. S. Nachet, Sen., the founder of the eminent firm of French opticians, which took place at his residence in Paris on the 28th ultimo, in his eighty-third year. He was one of the earliest in France to devote himself to the construction of achromatic objectives for the Microscope. In 1834 he entered the house of Chevalier, and during six years his exertions contributed largely to the reputation of that house for improvements in the manufacture of Microscopes. In 1840 M. Nachet commenced business as an optician on his own account, confining himself principally to the Microscope, and specialities required by surgeon-oculists. In 1842 he contributed a paper to the Académie des Sciences (tome xiv.) describing the construction of achromatic objectives in which curvatures of 0·5 mm. radius were employed. From that date he received the advice and encouragement of some of the leading scientific men of the Continent: Amici, Arago, Babinet, Regnault, Milne-Edwards, and later Drs. Lebert and Charles Robin entrusted him with the execution of numberless experimental devices. In 1843 he again appeared before the Académie des Sciences (*vide* tome xvii.) with improved high-power objectives, and his camera lucida for vertical Microscopes. In 1844 (*loc. cit.* tome xviii.) he exhibited a Microscope composed of a doublet with a concave ocular (since developed into the "Loupe de Brücke"). In 1845 (*loc. cit.* tome xx.) he produced improved high powers using a fourth achromatic combination. In 1846 (*loc. cit.* tome xxii.) he devised his erecting Microscope for dissecting, &c., which was described in Quekett's work. In 1847 (*loc. cit.* tome xxiv.) he brought out his well-known prism for oblique illumination to be used in combination with the mirror in the optic axis. At that date his son Alfred was admitted into partnership, and various forms of binoculars, &c., have since been devised by the firm, which are referred to in the popular text-books of the Microscope. For some years past M. Nachet, Sen., had taken no active part in the business. Those who knew him personally will remember his kindliness, and also the liberality with which he carried out the construction of experimental apparatus. His lifetime may be said to comprise the whole period of the development of the compound achromatic Microscope from the earliest doublets up to the latest homogeneous-immersion objectives.

We have also to record the death of a well-known eminent American optician Mr. Charles A. Spencer, which took place on September 28th at Geneva, N.Y., in his sixty-eighth year. Mr. Spencer commenced work as an optician immediately on finishing his studies at Hobart College. Upwards of thirty years ago he produced dry objectives having apertures of 170° and higher, one of which was specially commended by Dr. Robinson, of Dublin. Mr. Spencer's objectives were much appreciated by the principal microscopists in America, such as Professors Bailey, Henry, Bache, Pierce, H. L. Smith, and Drs. Woodward and Torrey. President Barnard, of Columbia College, N.Y., was mainly instrumental in inducing Mr. Spencer to send specimens of his objectives to the Paris Exhibition of 1878, where a gold medal was awarded for their excellence. Mr. Spencer leaves two sons who have been associated with him for some years in the production of microscope objectives. He was one of the earliest to produce immersion objectives having apertures exceeding the maximum of dry objectives of 180°.