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ELEMENTARY PHOTO-MICROGRAPHY.

By WALTER BAGSHAW.

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ELEMENTARY

PHOTO-MICROGRAPHY

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PREFACE.

BOOKS on photo-micrography, although numerous, are chiefly both expensive and perplexing, covering as they do much extraneous ground that has little or no interest for the beginner who wishes simply to learn how to take photographs through a microscope. Indeed, some of the works professing to deal with the subject of photo-micrography are little better than trade catalogues, and devote far more space to the description of various microscopes and accessories than to the elementary information generally desired. Others, again, specify expensive appliances beyond the reach of an ordinary person, so that the reader is deterred from taking up the subject at all.

Now, instead of filling the novice with dismay at the difficulties to be encountered, it is my intention to make the matter so easy that he may be encouraged to proceed.

When lecturing in different towns, I have been surprised to find what an amount of interest could be aroused in working men, many of whom have been stimulated to commence photo-micrography, and have sent me specimens of their early attempts along with expressions of gratitude for directing

them to a pursuit far more satisfactory than some which previously occupied much of their leisure.

A list of books upon the scientific side of the subject will be given to enable the amateur to pursue his study with more accuracy and more efficient apparatus than are contemplated for beginners with limited purses and scanty leisure.

I am aware that some of the methods recommended are contrary to the practice of scientists, but I am not writing for experts in possession of high-class apparatus, but for beginners, and I do claim that an amateur with simple apparatus may produce results which, though not perfect, are good and acceptable for nearly all purposes. A doctor, for example, who may wish to photograph certain specimens of only temporary interest, is enabled to do so by simple means perhaps already at command, and with sufficient exactitude to serve his purpose, even with high powers, whilst with low powers he need not be ashamed of comparing results with the best.

WALTER BAGSHAW.

Batley.

CONTENTS.

CHAPTER I.

INTRODUCTORY.

CIRCULATING SLIDES—THE LITTLE SPECIAL APPARATUS NEEDED—THE USE OF AN EYEPIECE—FIRST ATTEMPTS.

Although the sense of sight enables us to see the many forms around us, there is a world as absolutely invisible to the unassisted eye as the familiar objects of life are invisible to the blind. To those who have eyesight, however, the microscope bestows as great a power of vision as the gift of sight would bestow upon the blind, for it enables them to penetrate the secrets of nature's realm, which without such assistance would for ever remain a mystery.

A very small magnification will often reveal details of construction sufficient to call forth exclamations of surprise, and, indeed, with microscopists it is a matter of common knowledge that whole insects or parts of plants viewed under a low power will excite more astonishment than the resolution of a difficult diatom under the very highest power. For instance, a spider magnified ten times seems more wonderful to the uninitiated than the markings of *Amphipleura pellucida* magnified 3,000

times. It is only when the *tyro* attempts to obtain these results himself that he realises the difficulties.

Now the possessor of a microscope has three ways of showing the special objects of his study to his friends. Firstly, he may exhibit the mounted specimens in the ordinary way, when every individual must of necessity look down the tube of the microscope; or, secondly, he may attach the microscope to a lantern and throw the enlargement upon a screen visible to all; or, thirdly, he may photograph the objects through the microscope, and thus obtain a permanent and ever available record.

It is only with the last of these methods that we have to deal at present, and it is taken for granted that the reader is already familiar with the use of the microscope, since it is much easier to instruct the microscopist in the mysteries of photography than it is to teach the amateur photographer the uses of the microscope. If the reader, then, is not conversant with the microscope he is recommended to study some good textbook on the subject before attempting to photograph through an instrument he does not understand.

But there are many microscopists who are also photographers, although they may never have tried the special branch of photo-micrography. To such there is a fund of pleasure in store. As a fascinating pursuit it has no equal. Independent of weather, scenery, and sunshine, the photographer may be seated at a comfortable fireside by gaslight and produce pictures both marvellous and beautiful. Every

article at hand is capable of being pressed into service, or if the operator dislike the preparation of his own objects he has at command for a small sum about 40,000 fine specimens of infinite variety, which can be sent by post from the circulating departments of Mr. C. Baker, and Messrs. Watson and Sons, of Holborn, London.

From his negatives the worker may make both prints and lantern slides, and so provide a feast of entertainment and instruction for himself and his friends.

But the beginner is warned against letting the mere pursuit of pleasure keep him from the educational advantages of systematic work. Hence, instead of making desultory efforts, he is strongly advised to take some special subject and master it before proceeding to another. For instance, he may select plant life, beginning with the simple cell, modes of cell growth, shapes of cells, cell contents, and so following on to the various modifications in highly-organised plants. Seeds, pollen, flowers, and sections of stems are also interesting objects to be photographed, the study of which should be continued with their *delineation*.

Thus pleasure and knowledge will go together, and every step will prove an incentive to further progress.

On the other hand, if the worker take up the matter as one merely for amusement he is not likely to master the difficulties that will present themselves

sooner or later, failing which he is the more likely to get tired and discouraged.

The business man as well as the professional man will find endless ways of turning the microscope to profitable account, when once the art of illumination and knowledge of correct exposure are overcome.

The results of photo-micrography (pronounced foto-mi-krog-ra-fi) are indisputable, and are far more faithful than any sketches made by the most skilled artist. The camera-lucida, that did so well for our fathers, is now a thing of the past, except where simple outlines only are wanted, yet a few years ago, even in our large cities, there were few persons capable of producing good photo-micrographs, while to-day they are produced in every branch of science.

Only so recently as 1891 I had occasion to require some photo-micrographs of sand, but to my surprise I was informed that in a city of 400,000 inhabitants only two or three persons outside the Medical School were competent to do the work.

There is no reason why the art should be confined to the select few, for, after all, the mysteries are not so great that they may not be lessened by a few preliminary trials, one or two failures being sufficient to indicate the direction in which an alteration should be made. The apparatus need not be at all costly in order to produce good results, although for high-class scientific research everything must necessarily be of the best.

Consequently, for the purpose of this book a special room with massive foundations in a special

district free from the vibration of passing vehicular traffic, monochromatic and electric or limelight, the heliostat for sunlight, expensive apochromatic lenses, or even specially-corrected microscope objectives will not be requisitioned for carrying out any of the instructions hereinafter given, but only such simple apparatus as the ordinary photographer possesses, with the addition of a microscope. Indeed, for low-power work, a camera, a paraffin lamp or lantern, and a few home-made articles are all that are essential, no microscope being required, as the operation is one of simple enlargement. The whole of the processes hereinafter described are intended to be carried out by artificial light.

There is a difference betwixt the visual and the actinic foci, and objectives corrected for photography are sold, but ordinary objectives made by good firms give results not to be despised. Even with high powers tolerable negatives can be obtained, and the brain work of a practical manipulator will often compensate for lack of expensive apparatus.

The use of eyepieces is condemned by some writers without much reason. If the eyepiece be not used a long extension of camera is needed, whereby the apparatus becomes troublesome, and the result is not one jot better than when the eyepiece is employed. The loss of light occasioned by its use is more than compensated for by the compactness of the arrangement, whereby the operator may see or control the whole of his focussing

and lighting from one position. A trifle longer exposure is of no moment to a beginner, since the time lost in this way is saved in the facilities offered for focussing. The errors of objectives also are corrected by eyepieces, and good results can be obtained when using them for photographic as for visual purposes. The C eyepiece, although giving great power of enlargement, is not recommended when a lower power will do. Yet the writer has been able to get capital results with C eyepiece when the same magnification had been obtained by a low eyepiece and a high objective with less success.

But clearness of definition must never be sacrificed for the sake of a larger picture. A crisp negative may be enlarged, whilst a larger image wanting in sharpness is valueless. The only advantage to be gained by a C eyepiece is that it allows a low-power objective to be used with greater depth of focus. For dark ground illumination and for polariscope work the eyepiece may be dispensed with at the sacrifice of magnification. Great care, however, must be exercised when not using the eyepiece, or the reflection from the interior of the body tube will manifest itself in the form of a bright central spot on the negative.

The use of an eyepiece removes this entirely, but by way of object lesson let the reader take a microscope that is not dead blacked inside the tube, and throw the image of an object on to a sheet of paper. After getting even illumination with the

eyepiece in position remove the eyepiece, and immediately a bright central spot of light will appear on the paper. If the paper be now moved to or from the end of the microscope, the bright spot of light will gradually expand into a bright ring of light, and then resolve itself into a point again. The whole surface of the illuminated disc is, of course, much more brilliant without the eyepiece, reducing exposure considerably, yet the defect in uniformity of illumination would spoil the negative. On replacing the eyepiece the bright spot of light vanishes, and the whole disc is equally lighted, though not so brightly as before.

First attempts should be made with well-defined objects possessing contrast, such as the section of a stem, rather than with those that are very transparent all over.

CHAPTER II.

SIMPLE APPARATUS.

PHOTO-MICROGRAPHY WITHOUT A MICROSCOPE—APPARATUS FOR THE WORK—THE ILLUMINANT—MAKING THE EXPOSURE—OBJECTS SUITABLE FOR WORK OF THIS CHARACTER.

It is desirable that the worker should have the whole of his apparatus within easy reach during the operations of centring, illuminating, and focussing the specimen without change of position; but in low power photography when no microscope is employed, this is not possible. Still, if he stand to his work instead of sit, it is only necessary to bend the body to the right or to the left in order to command a view of the field at both ends of his apparatus.

Instead of the microscope, an enlarging camera is used, which comes in useful afterwards for enlarging negatives, but a wood box covered at the open end by a focussing cloth will answer equally well. The handy man will readily see what portions he can make himself, and cut his coat according to his cloth.

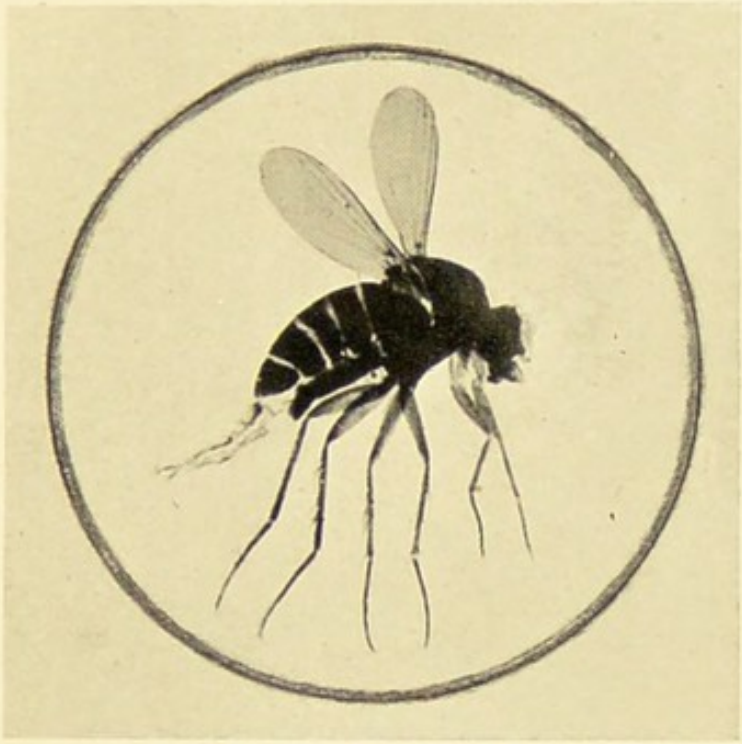


Fig. 12. Fantail fly.

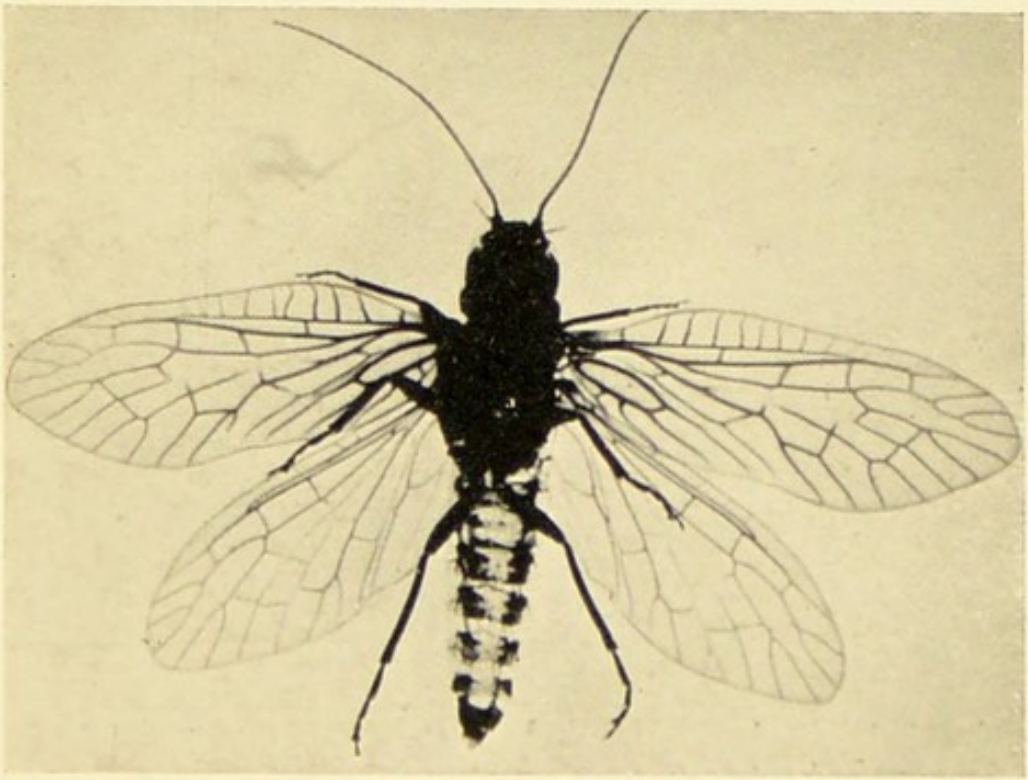


Fig. 13. Pearl fly. Enlarged from 3in. by 1in. slip, by quarter-plate camera.

If the reader possess a short focus lens, the enlargement may be made with a single camera. Assuming, however, that a quarter-plate camera with a lens of about 5in. focus is used, the ordinary dark slide must be replaced with a thin wood slide, such as may be readily cut from the lid of a cigar box. In the centre of this a hole is bored 7/8in. diameter —a size quite large enough for any specimens mounted in circular cells—and when the object is mounted in an oblong cell, another wood slide can be used with a hole 1½in. × 7/8in. instead of the circular one. A little below this large opening make two small holes with a pricker to receive two brass clips like those provided with the stage of cheap microscopes. These clips are to hold the glass object slide in position.

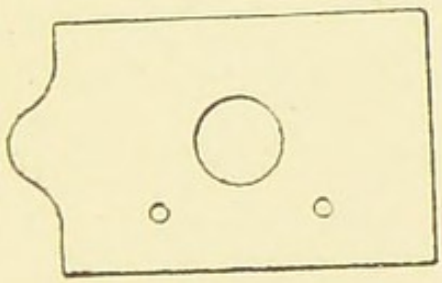


Fig. 1.

Fig. 2.

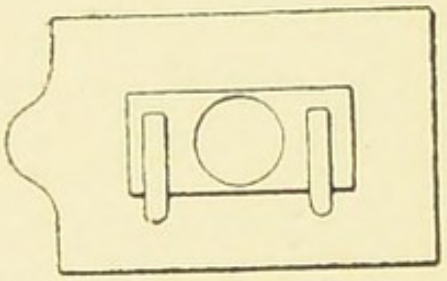


Fig. 3.

Fig. 1 shows the wood slide, fig. 2 the spring clips, and fig. 3 the glass object slide held in position.

Whole insects, and in fact any object too large for the microscope, may be photographed in this way, and some of them make beautiful lantern slides; but anything larger than would be mounted

on a 3in. × 1in. slip must be considered as coming under the head of ordinary photography.

A piece of very strong cardboard or thin wood is next cut to fit the end of the enlarging camera, and in the centre a hole 4in. × 3in. for a quarter-plate, or 3in. square if a lantern plate is to be used, is made. I prefer the lantern plate size myself, as in many instances it does away with the necessity of making a positive, the negative itself making as good a slide as if a positive were taken from it. For many objects I even use a size still smaller—3¼in. × 2⅛in., or the ordinary quarter-plate cut in two.

A glass cutter (price one shilling) will enable the owner to utilise his plates with great economy at times, if such be any consideration. For testing exposure a cut plate will do quite as well as a whole one. Consequently, the disappointment of wasting material is not felt so keenly.

Whatever size be adopted, after cutting the hole ⅛in. less than the plate each way, strips of cardboard must be glued down each side of the aperture to form grooves into which the plate may be inserted. Another strip on the bottom will keep it from dropping. These grooves should be wide enough to receive both a dry plate and a backing piece of black cardboard to keep any light from the back of the sensitised plate during exposure.

A slip of ground-glass, to be used as a focussing screen of the same size as the plate, must also be

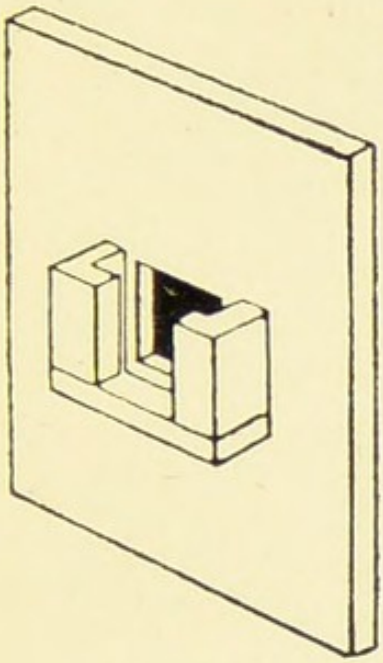


Fig. 4.

provided. This will slip into the grooves, fig. 4, whilst the focussing is completed.

The cameras and lantern should be placed as shown in fig. 5, with the centres all in the same line. A is the enlarging camera, B the small camera, C the ground-glass, and D the lantern with its front lenses removed.

A lantern with incandescent light is effective and clean, and is got ready with little trouble. A rubber tube being connected to the nearest gas bracket, the light may be turned on or off at a moment's notice. An acetylene lamp also gives a bright light, but is more troublesome, and cannot be left burning during development if all the processes be carried out in the same room. If a lantern be not

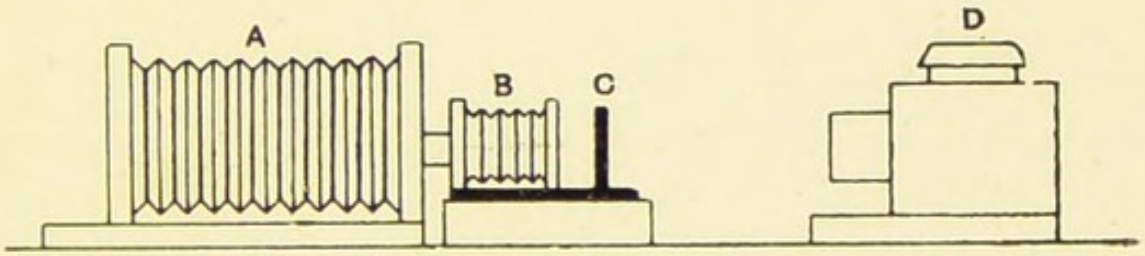


Fig. 5.

available, magnesium wire will answer, though the smoke from this is objectionable in ordinary households, where it is presumed the reader will usually work.

The projecting lenses mounted in the focussing tube of the lantern are not required, and may therefore be removed before commencing, and the 4in. condenser alone used. The prepared object is put into the clips, and the ground-glass into the groove at the opposite end. The object is focussed sharply by means of a focussing glass—the naked eye is quite unable to discern the point of best definition—and another piece of ground-glass is interposed near to the object, but not close to it, to distribute the light and secure even illumination of the field. The ground-glass should stand between the object and the lantern (C, fig. 5), and must be far enough from the object to be out of focus, or the rough surface of the glass will be shown in a coarse background on the negative.

We are now ready for the exposure. A cap is placed on the lantern, or a large piece of cardboard put against it, to keep the light from reaching the camera, and all the lights are lowered. The dark room lamp is lit, and the focussing screen gently removed from the grooves, replacing it with the dry plate and a black card behind that. There is no need of any covering cloth if the plate and card fit nicely into the grooves. Then the lantern light is turned up, and the cardboad or cap removed, letting the beam of light play full on the object for as many minutes as may be necessary. Information on this point will be given under the head of "Exposure." Again the lantern is capped, the light lowered, and the plate is removed to be developed

there and then, or put it in a box for another time. There is much less danger of disturbing the apparatus by this method than when using an adapter for the dry plate and drawing the dark slide in the usual way.

It will be understood that objects to be photographed in this way must be transparent, but opaque objects may readily be taken by altering the mode of illumination. When this has to be done, the bellows of the quarter-plate camera should be closed entirely, the wood slide having been withdrawn and mounted on a stand at the same distance from the lens that it would have occupied had the object been transparent. A clear space between the lens and the object will thus be left. A paraffin lamp and bull's eye are now brought round to illuminate the opaque object from the front instead of from the back, as in previous attempts.

A silver side reflector, usually of the parabolic form, will take the rays of light from the lamp and distribute them over the object, if it is not too large. Unless properly done, one side will be sharp and the other side fuzzy, owing to deficient lighting. Magnesium will be found to give good light and shade with this class of object.

CHAPTER III.

THE MICROSCOPE AND ACCESSORIES.

THE MICROSCOPE—ITS ESSENTIALS—A SIMPLE BASEBOARD—THE FOCUSSING GLASS—THE BULL'S EYE CONDENSER AND LAMP—MAGNESIUM RIBBON.

A good second-hand microscope may often be purchased at less than half its original cost. Cheap microscopes by unknown makers are useless for photography, therefore it is better to get a good one second-hand than a poor one new. In selecting such an one the following points are desirable:

The maker should be one of good repute.

The body tube should be preferably of short length with full size eyepiece and coated dead black inside.

It should have

A rack and pinion substage motion for adjustment of the condenser with a centring arrangement,

An iris diaphragm and disc plate,

A mechanical stage, and

A coarse and fine adjustment.

The advantage of a short tube is seen in the much larger field when using low powers. If the microscope have a polariscope attachment, all the better, but this is not essential. It should have two eyepieces, A and C, and a battery of good objectives, say, to begin with, 3in., 2in., 1in., ¼in., to which may be added afterwards ⅛in. and 1-12in. oil immersion, as the reader feels his way to use higher powers. All these should be kept free from dust and carefully cleaned with wash leather before use. Cleanliness throughout is of the highest importance. A mere dust over with a pocket handkerchief is not sufficient. The mounted object to be photographed should also be rubbed back and front, for it is astonishing how readily dust and hairs adhere, and it must be examined with the focussing glass before one can be satisfied that it is clean.

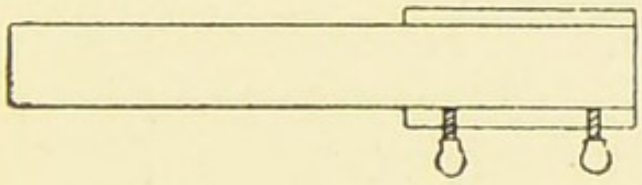


Fig. 6.

Fig. 7.

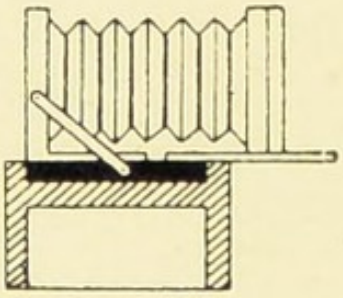


Fig 8.

Caution when touching the oil lamp not to grease the fingers is advisable. A short black velvet tube to fit over the eyepiece will be required to connect the microscope with the opening in the quarter-plate

camera, the lens having been removed, as it is not required when using the microscope. A small iris diaphragm called a Davis shutter will be found useful for getting better penetration and definition. This screws into the body tube of the microscope at one end, and receives the objective at the other end. It removes any halo or glare, and enables a sharp picture to be taken. For feathers, eggs of insects, and polycystina it is almost indispensable.

A carpenter may be got to construct a simple baseboard, on which the lamp, microscope, and camera may be placed. At one end of the board two flanges are fastened, between which a block bearing the camera on the top slides freely to and from the microscope. This sliding block again has flanges to receive the small camera and keep it rigidly in position whilst drawing the dark slide. Two thumbscrews in one flange of the baseboard will fix the sliding block, and will secure both block and camera after connection with the microscope by means of a velvet tube has been made.

Note that the bellows of the camera must be capable of full extension when placed in the recess on the top of the block. Thus any degree of enlargement may be obtained by racking the bellows in or out without disturbing the connections. A reference to the sketch, fig. 8, will make this clear.

Fig. 6 is a board about 5ft. long 8in. wide, and 1in. thick. Fig. 7 is the end view showing flanges, say, 2in. deep. The sliding block, fig. 8, slides freely between these flanges, and is fixed by the

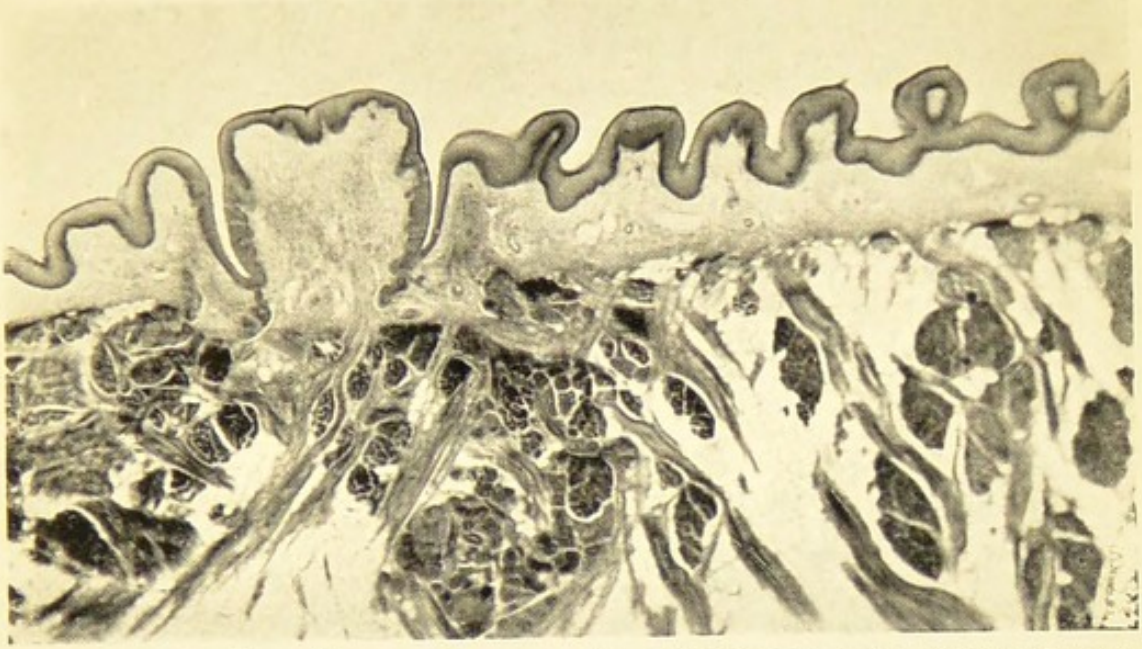


Fig 14. Section of human tongue. 3in. objective at 20in. No condenser. "A" eyepiece. Chromatic plate. One minute.

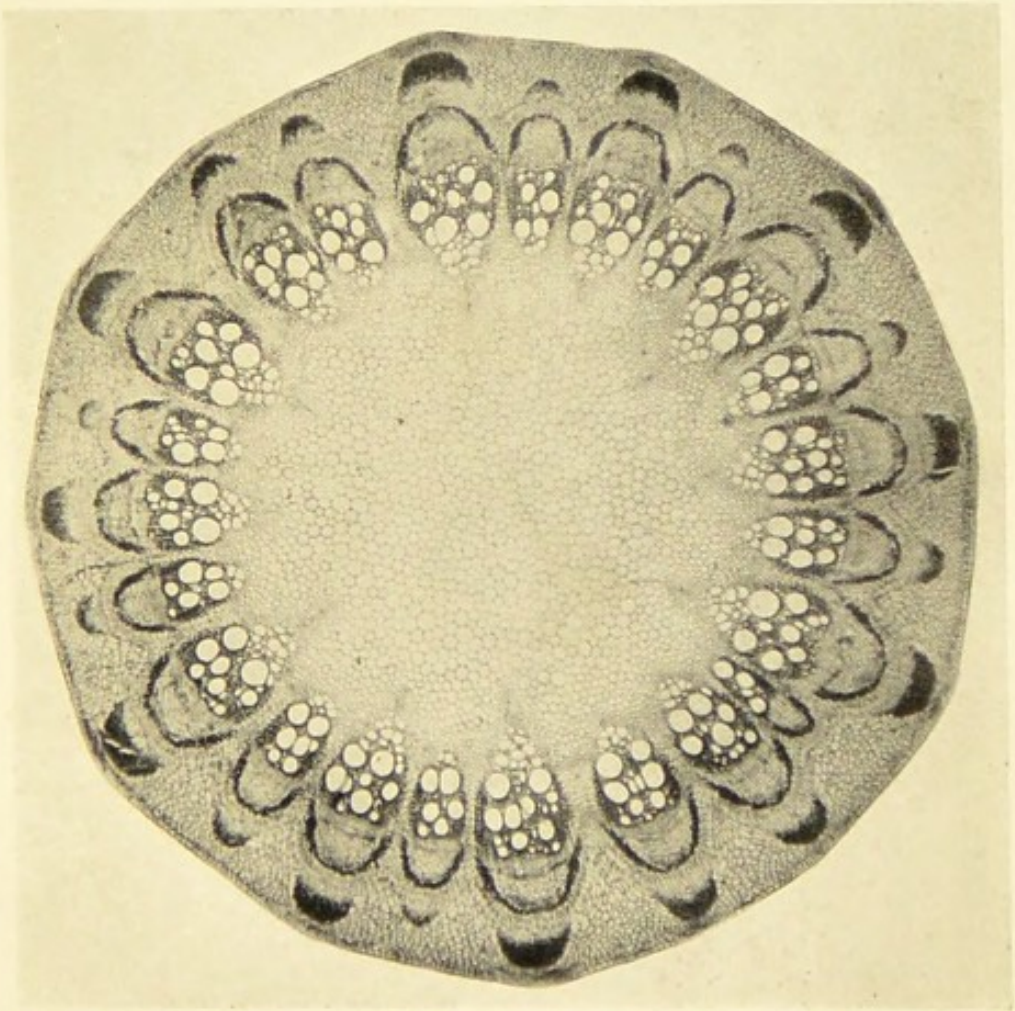


Fig. 15. Section of clematis stem. 3in objective at 18in. Rapid plate. "A" eyepiece. One minute.

thumbscrews. The camera, microscope, and lamp are seen in position in fig. 9.

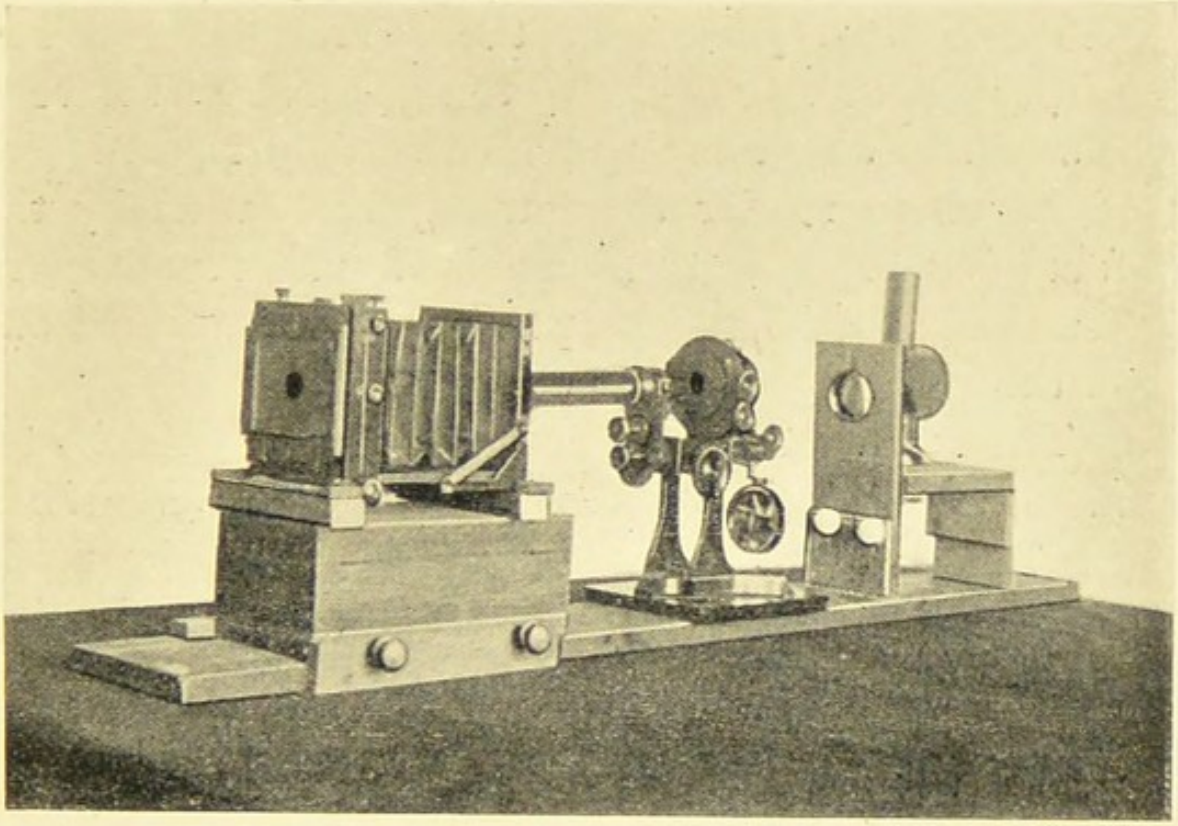


Fig. 9.

For a focussing glass any of the ordinary type will do, and when once set to suit the sight of the owner, will need no further alteration. A mark with lead pencil must be made on the rough side of the ground-glass screen, and then, turning it over, the focussing glass is put in contact with the smooth side, the lens being screwed to and fro until the pencil mark is clearly in focus. It is important to rest the foot of focussing tube upon the glass whilst making the adjustment. The focussing glass may

then be slid over every part of the screen, after the projected image is thrown upon it, to ascertain whether each part of the object is equally in focus.

When high powers of the microscope are employed, the rough side of the glass should have a few places about the size of a shilling rubbed with glycerine to render them transparent, whereby the focussing of delicate fibres is found much more certain. One should be put in each corner and one in the centre.

The paraffin lamp and condenser are better mounted on one stand than when separate. When used separately, the adjustments have to be made every time, whereas when the lamp and condensing lens are capable of being moved about together without disturbing their relative position, one setting is sufficient. Several good lamps on this system can be bought, but an equally efficient arrangement may be made, as shown in the sketch, fig. 10.

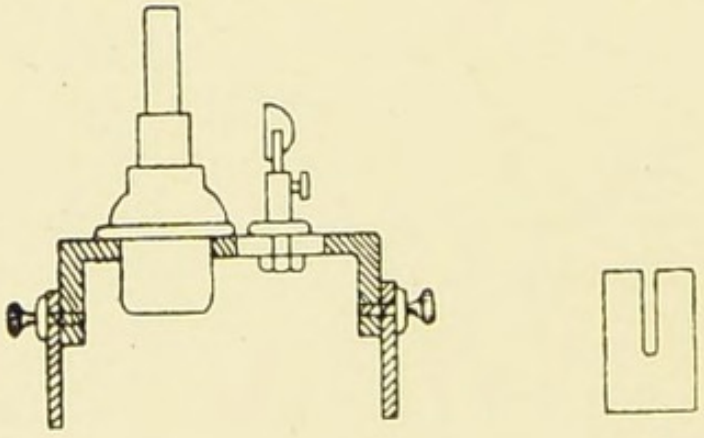


Fig. 10.

Fig. 10 shows a simple wood frame (having a circular hole for a paraffin lamp, and a slot in

which a tube bearing the bull's eye may slide to and from the lamp) supported by two loose ends free to rise and fall. The bull's eye can be raised or lowered at will, and the centre of the flame can thus be adjusted to suit the centre of the microscope. All adjustments are easily made, and, having once been perfected, the time required for setting it in position for work is reduced to a minimum.

A metal chimney is preferable to glass, and a shade to drop over the lamp chimney is desirable. To set the lamp properly the flame is first turned gradually up to its working height, and put with the edge of the flame (not the flat) towards the condenser. The flat side of the bull's eye is put next the flame, at its proper focal distance. Having done this, the photographer's next step is to look right into the lens through a pair of neutral tint spectacles, and to raise or lower the flame until the whole is brilliantly illuminated. If dark spots appear in the lens it is moved towards or from the flame to get a bright circle of light. If this does not give the desired result, raising or lowering the lens must be tried. A little experimenting will soon give the correct position.

One advantage of an oil lamp is the absence of that intense heat which gives the user of limelight so much trouble.

Magnesium.

Magnesium ribbon burns at the rate of about twelve inches per minute. It is purchased in coils,

and can be fed through a tube. If care be taken to get uniform illumination by means of ground-glass, then much time is saved by this light, which is rich in actinic rays, but the beginner is not advised to try it until he has a good knowledge of all the points to be observed in the taking of a perfect negative. When using very oblique illumination an exposure of two minutes with magnesium will be found equal to sixty minutes with paraffin lamp.

CHAPTER IV.

ILLUMINATION.

ILLUMINATION—ADVANTAGES OF ARTIFICIAL LIGHT—A SIMPLE OBJECT WITH A LOW POWER—DIATOMS—WORKING WITH POLARISED LIGHT—OPAQUE OBJECTS—DARK GROUND EFFECTS.

Artificial light being more constant than daylight, it follows that exact exposures may be repeated without risk of failure. The landscape photographer has no power to alter the prevailing light and shade, whilst the photo-micrographer can modify them at pleasure. But, on the other hand, the latter will find difficulty in getting any contrast at all when dealing with very transparent objects, and it is here that his individuality will be manifested. The iris diaphragm will sometimes be needed; at other times it may be the polariscope, especially for crystals, or perhaps the colour screen must be employed. Which method and which colour screen will only rightly be selected after experience has been gained. If the worker prepares his own object he can often stain it to bring out its details. However, all these matters will have to be dealt with separately.

Commencing with a simple object and the lowest power, we first set up the baseboard, with lamp, microscope, and camera duly placed in position (see fig. 9), but as an object may be photographed either by direct transmitted light, reflected light, and with dark ground or light ground, we will consider transmitted light and a light background first.

Having placed the object on the stage of the microscope, it is focussed with the A eyepiece, the camera and sliding block having been removed for this purpose. No substage condenser is needed for powers lower than 1in.; therefore the critical light to be used for high powers may be replaced by the ordinary parallel rays from the bull's eye after the paraffin lamp has been set according to the instructions previously given. The eyepiece is next taken out and a piece of white cardboard placed about 12in. away from the end of the body tube to act as the screen, and receive a projected image from the microscope. The disc of light will possibly be found brighter in one part than another. The lamp is moved sideways until the whole disc is equally illuminated with the object well defined in the centre. The focussing may be altered for this purpose. The eyepiece is replaced to see if the field be still uniformly lighted, a slight adjustment of focus again being necessary. If the lamp be in the right position the disc of light will be sharp and uniform right up to the edge of the circle with or without an eyepiece. The cardboard is taken away, and the camera brought up to the microscope with

the velvet connecting tube over the eyepiece. The sliding block is secured by the thumbscrews, and the figure on the ground-glass at the end of the camera is examined. If the magnification be too small the camera is racked out, or if too big closed. The object is centred by means of the mechanical stage. If size and position are correct fine focussing may be performed with the glass through the transparent places at each corner and in the centre of the screen.

Perhaps the object will be too brilliantly lighted, and the whole be drowned in a flood of light. If so the iris diaphragm is closed a little, not too much or diffraction effects will result, the aim being to increase contrast by securing dark outlines on a light screen. Either the Davis shutter or the iris diaphragm will give contrast. When this is secured the dark slide may be inserted, and an exposure made.

Objects such as polycystina and diatoms show much better as light figures on a black ground. To obtain this effect the substage condenser and diaphragm plate will be needed. Let them therefore be attached and the microscope focussed on the object as before. The lamp is turned quite round, keeping the edge of the flame at the same distance from the object as it will be when reversed, and the edge of the flame focussed on the object. This is termed "critical light," the best possible illumination for examination purposes, though too small in area for low-power photography. We must there-

fore find some means of diffusing it over the whole surface of the object, and this can be done by interposing the bull's eye. The lamp is again reversed with the bull's eye previously set in focus, and an evenly-lit disc on the cardboard is sought as in the method last described. Having got it satisfactorily, the central rays are stopped out by means of a disc in the diaphragm plate, so that an annular ring of light only enters the condenser.

If it be diatoms we are photographing they will now be seen glittering like pearls upon black velvet. The microscope is connected up, focussed, and an exposure made. Longer exposure must be given than with direct light. The mirror of the microscope is not required. It is well to make sure that the substage condenser is properly centred with the optical axis of the microscope before commencing.

When photographing without the eyepiece a bright spot in the centre of the illuminated disc will appear if the body tube be not lined with black velvet or otherwise dead blacked. This is caused by reflection, and is specially noticeable when using polarised light, but the eyepiece removes this defect entirely, though with greatly prolonged exposure.

Occasionally the substage condenser may be lowered with advantage, and a more even illumination secured, although at a sacrifice of brightness. When the markings of certain diatoms are to be seen at their best the light should be thrown on them obliquely by means of a crescent-shaped dia-

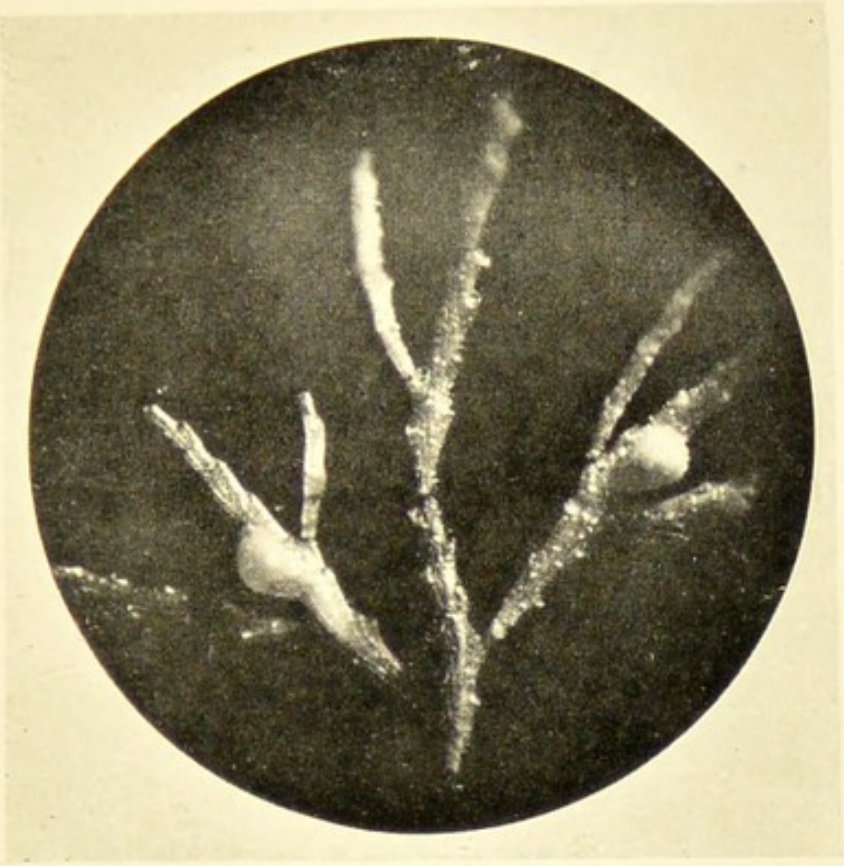


Fig. 16. Coralline. 3in. objective. No eyepiece. Slow plate. 18in. from object to plate. Five minutes.

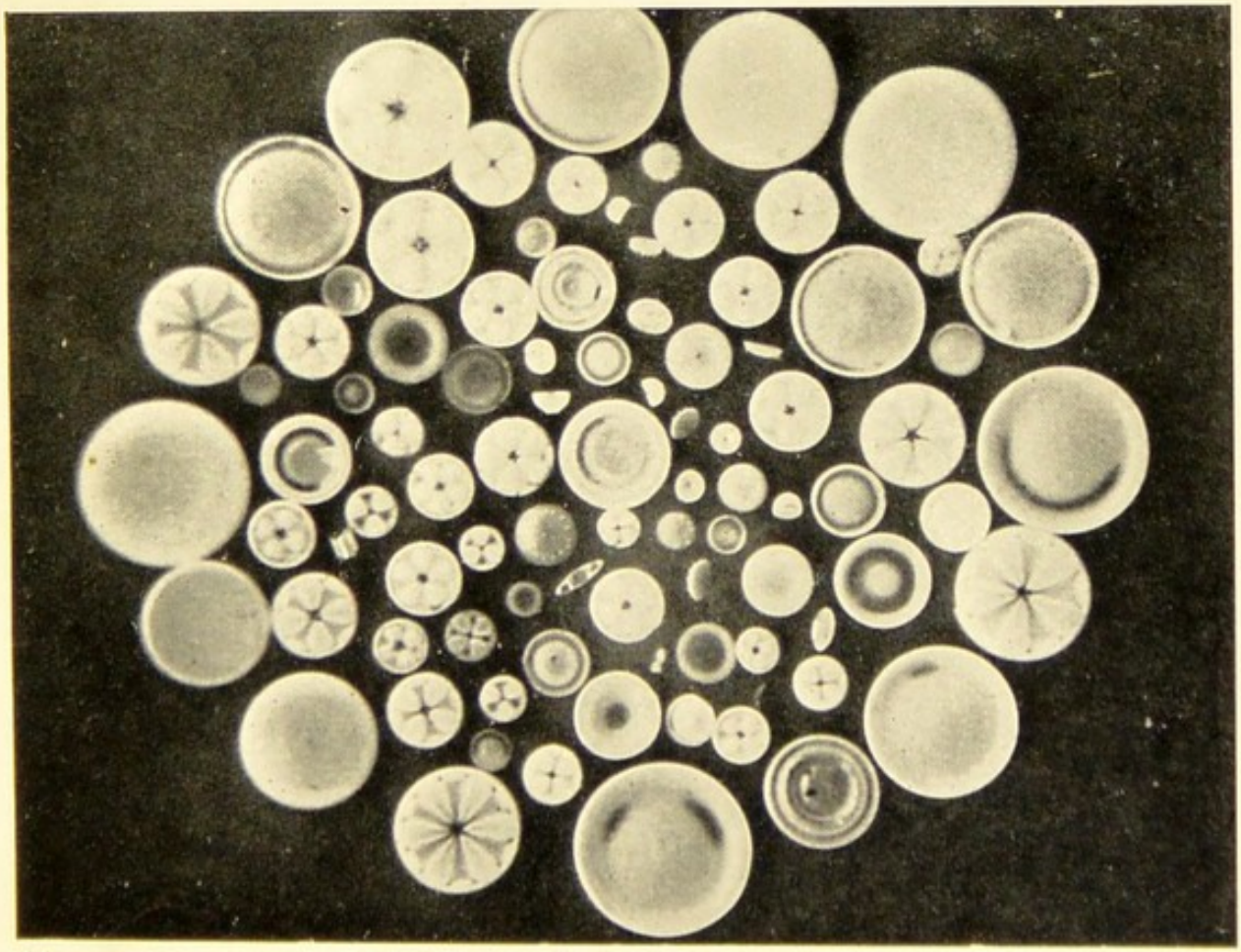


Fig. 17. Diatoms. "A" eyepiece. 2in. objective at 23in. Slow plate. Four minutes

phragm, taking care that the lighting of the ground-glass screen is both uniform and sufficient to ensure a background of tolerable density. Oblique light, although very good for visual inspection, is ill adapted for photography, and without great care will result in a blank negative, even after long exposure.

The writer has never found the Lieberkuhn of any advantage in illuminating opaque objects. A reflector called a vertical illuminator may be tried when the lens approaches so near to the object that it is difficult to project a beam of light from the side reflector. It is especially useful for photographing metals with high powers or objects mounted dry on cover.

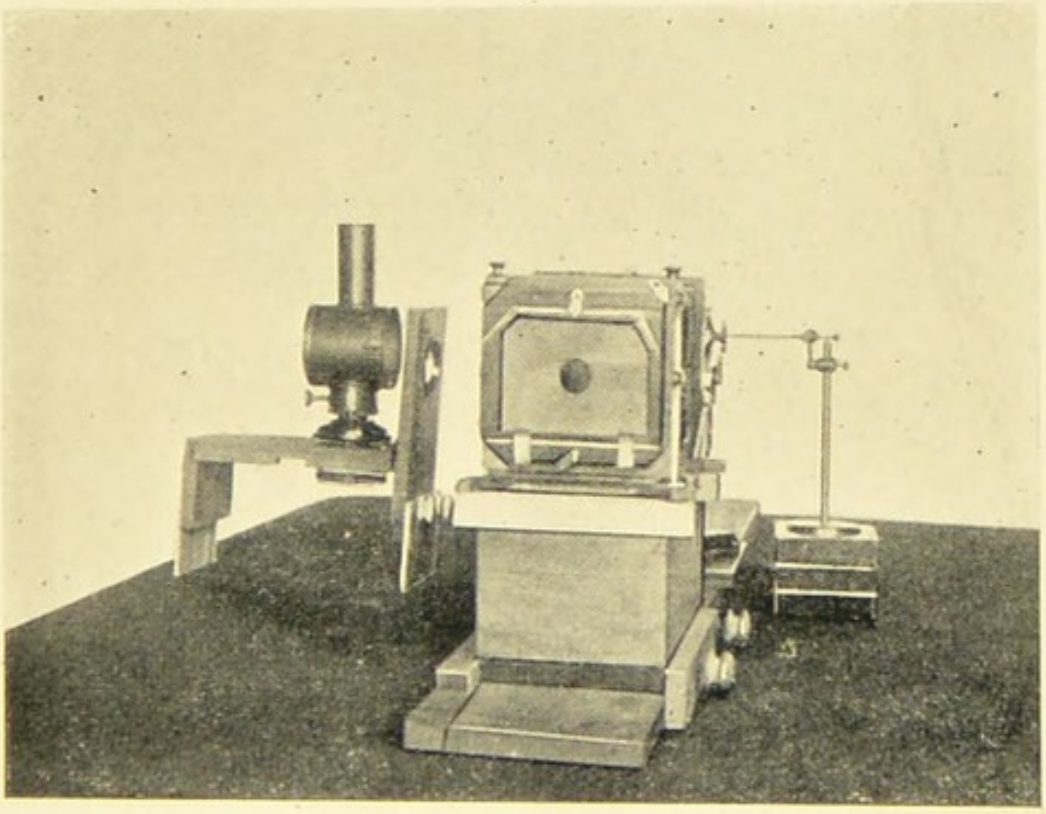


Fig. 11. Arrangement of the side reflector for opaque objects.

CHAPTER V.

Focussing Screens—Trying Effects—Oil Immersion Lenses—Test Objects—Measuring the Amplification with any Extension of Camera—The Polariscope—Colour Screens.

Quite a chapter could be written on focussing screens and the mode of preparing them. Fine ground-glass screens can be bought with transparent circles (about 5/8in. diameter) in the centre and four corners, made by cementing thin microscopic cover glasses on with Canada balsam. These will answer all purposes. Some beginners work with a focussing cloth, underneath which they get quite hot and exhausted. If the gas in the room be turned down, there is no necessity for a cloth, and focussing can be carried on with comfort. It is well to sit down to the work and take it easy; standing and bending the back are tiring.

To focus, the focussing glass is held in one hand, leaving the other hand free for focussing first with the coarse and then with the fine adjustments; and for moving the mechanical stage and iris diaphragm, all of which may be easily reached. The rough focussing should be done through the eyepiece, with the camera and sliding block removed, as explained previously.

After the camera is replaced, a little time in trying different effects will not be wasted. The effects of closing the iris diaphragm, or a slight oblique light if fine markings are desired, or plain ground-glass between the condenser and the lamp if white diffraction lines are too conspicuous, may all be tried. Perhaps a coloured glass may be better. Then when a suitable result is obtained, one has to be very accurate with the fine adjustment, for everything else goes for nothing if correct focus be wanting.

A vertical camera is better for oil immersion objectives, though there is no difficulty when using them in the horizontal position, if only just sufficient oil be added to make the connection between cover slip and objective. A drop of oil will remain for hours without running or spreading, provided it be carefully and not too profusely applied.

In focussing with high powers, the danger of cracking the cover glass is lessened if the mounted slip be raised from the stage at one edge, using a finger nail for this purpose, and roughly following up the slip until it is flat on the stage again, when the fine adjustment comes into play.

There are certain slides sold as test objects, and if the photographer wishes to satisfy himself that his objectives possess power of penetration, definition, flatness of field, and coincidence of visual and actinic foci, he cannot do better than test the value of his lenses by taking a photograph of some well-known object suitable for the power used. Any

good book on the microscope will give information on this point. Markings of diatoms, the proboscis of the blow fly, the pygidium of the flea, podura scales, and sections of wood are well known objects for such a purpose.

To measure the amplification with any extension of camera after photographing the object, a micrometer is placed on the stage, and the divisions on it are photographed, keeping the camera extension unaltered. The enlargement is measured, and divided by the known distance between the spaces on the micrometer. Thus if 1-100in. on the micrometer measures 1in. on the photograph the enlargement is 100 times. Or the same result may be got by means of the camera-lucida, if the paper be placed as much below the camera-lucida prism as the ground-glass screen was from the eyepiece. For purposes of measurement a 10in. tube is the standard, and a negative taken ten inches away from the eyepiece will give an enlargement equal to that seen by the eye when looking through the eyepiece.

If the camera be now halved in length the magnification is halved, and if the camera be doubled the increase is in proportion.

A table showing the enlargement due to the various eyepieces and objectives is given by most makers in their catalogues, and may be referred to for ready reference.

Crystals are too transparent for ordinary photography, but can be brought out by the aid of the polariscope, which shows their form in many

colours. It will be found that sober tints yield better negatives than blue and yellow; the mica or selenite, therefore, can be selected accordingly. A dead black body tube is essential, and the most suitable powers are 2in. and 1in. objectives. The eyepiece is dispensed with to compensate for the loss of light through the prism. Orthochromatic plates, preferably backed, are used for this class of work, and in rotating the prism a position can be selected that passes much more light than other position. Perhaps the position, however, may not give the most desirable colours. Should this be so, try a change of mica or selenite, and if not now satisfactory, adopt such a medium position of the prism as shall be found to combine the greatest possible amount of light with satisfactory contrasts of colour. With the polariscope the time of exposure is about doubled.

In landscape photography, colour screens are used to obtain correct colour values, but in photo-micrography they are used for quite a different purpose, viz., to secure contrast. For instance, bacteria and many anatomical and vegetable sections are so transparent that they have to be single or double stained before it is possible to differentiate their form and structure. In their original colourless state they would never give a well-defined photograph, hence artificial contrasts have to be produced by staining. The general rule for determining the particular colour screen to be used for insertion between the light and the object during exposure

is that it should be the complementary colour of the one on the object. Thus, if the stain be red, a green screen must be used, because two complementary colours superposed produce blackness, and blackness, or absence of light, will give more or less transparent places on the negative, an essential element in the production of vigorous pictures. Experiment alone will teach the student just the right tint to employ. He should, therefore, have a selection not only of colours, but of light and dark shades. When colour screens are used, the acetylene light reduces exposure, and gives better results than the oil lamp. Orthochromatic plates must be used in every case.

CHAPTER VI.

Exposure—Discoloured Balsam—An Exposure Record—Examples of Exposure.

So much depends upon the light, the power of lens and eyepiece used, the colour and opacity of the object, camera extensions, etc., that only an approximate estimate may be made from the results of another worker; but the exposures tabulated hereafter were obtained with a paraffin lamp having a wick one inch wide. A word of warning may be given concerning specimens mounted in balsam. If one of these show patches of deeper colour in some parts than others, or if the gold size, marine glue, or other material of which the cell is constructed has dissolved and stained its contents, it should be rejected forthwith, for no amount of tinkering will give a good negative. Slides deep yellow on one side and perfectly transparent on the other, whilst not unfit for visual examination, are quite unsuitable for photography. This shows that some attention ought to be paid to the quality of the mounting.

A record of all exposures should be kept, entering the failures as well as the successes; it should note the plate used, the class of object photographed with its characteristic quality, the exposure, the distance of the plate from the object, and the result with each power and with each class of illumination. Supposing this to be done, and one wishes to know

what exposure to give to a botanical section stained red, using a 2in. objective and the A eyepiece, reference to the register shows, say, the following:

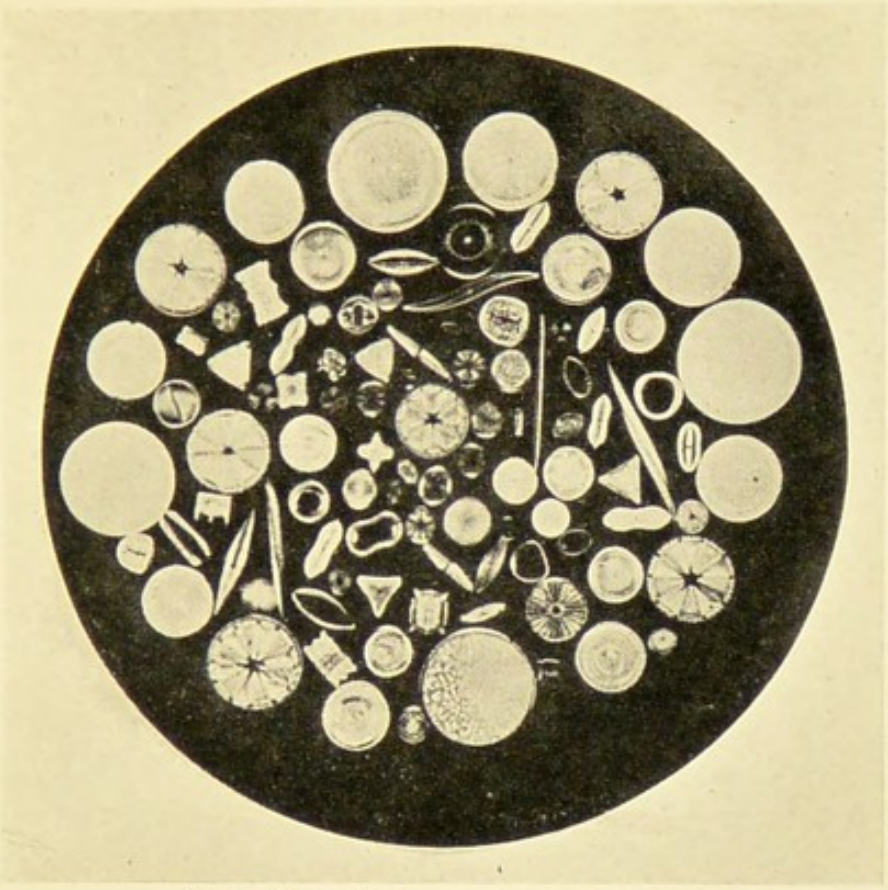
TRANSMITTED LIGHT.

2in. objective. "A" eyepiece.

PLATE.	OBJECT.	CHARACTERISTIC.	EXPOSURE.	DISTANCE OF PLATE FROM OBJECT.	RESULT.
Ilford ordinary.	Stem of clematis.	Stained red.	2 min.	20in.	Slightly over exposed.

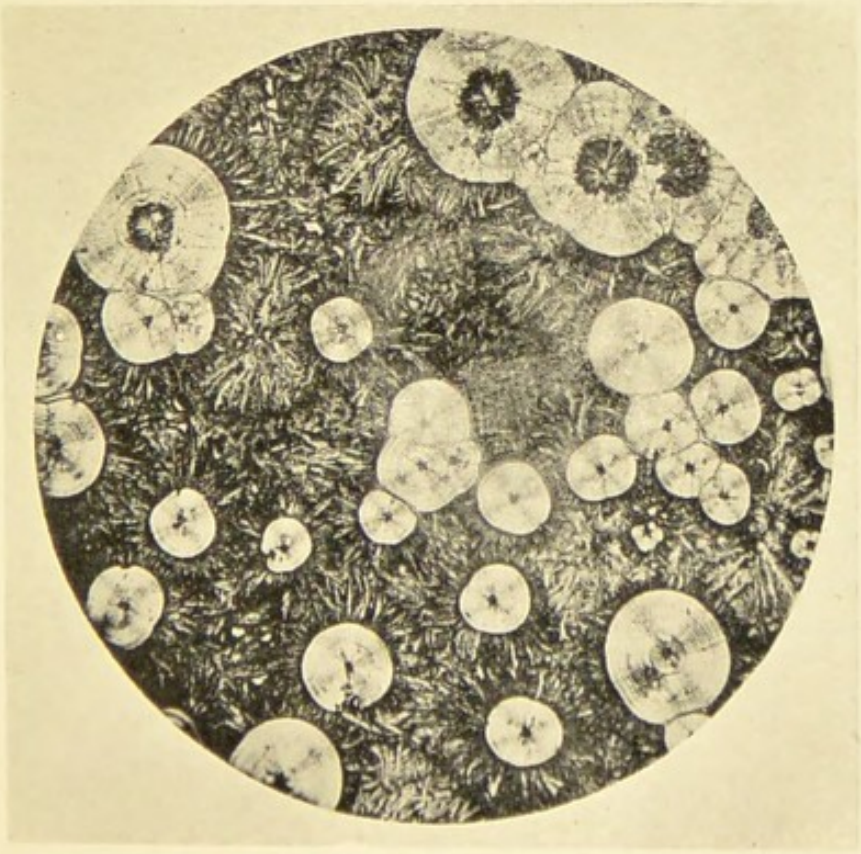
This will give an idea of the correct exposure for any similar class of specimen. It is folly to rely on the memory alone, like so many landscape photographers do. Far better take every precaution suggested by previous experiments to ensure correct exposure. One must not move about during the time of exposure, for vibration will spoil the sharpness of any negative, especially with high powers. It is not necessary, however, to remain inactive, for the gas may be turned full on, and the time occupied by reading or writing. When very long exposures are made, the worker may even leave the room and return at the end of an appointed time, so being free to do other things meanwhile.

The conditions governing correct exposure are so varied that no rule can be stated, and the following examples are merely given to point out the probable variations likely to occur in photographing assorted specimens. The distance of the object from the plate was about eighteen inches, the source of illumination a paraffin lamp with a one-inch wick.



WITH DARK GROUND ILLUMINATION.

Fig. 18. Diatoms. No eyepiece. 1in. objective at 21in. Slow plate. Ten minutes.



WITH POLARISED LIGHT.

Fig. 19. Brucine. No eyepiece. 2in. objective at 24in. Chromatic plate. Ten minutes.

3IN. OBJECTIVE.

Transmitted Light.	*Section of Human Tongue.* Red. "A" eyepiece. No condenser. Chromatic plate. One minute.
	Leg of Fly. Brown. Ground-glass interposed between lamp and object to secure sharpness of hairs and reduce the white diffraction effects. "A" eyepiece. Slow plate. Four minutes.
Dark Ground.	*Polycystina.* Slow plate. Webster condenser. "A" eyepiece. Four minutes.
Reflected Light.	*White Coralline.* No eyepiece. Slow plate. Side reflector. Five minutes.

2IN. OBJECTIVE.

Transmitted Light.	*Beetle's Eye.* Section. Slow plate. Three minutes. "A" eyepiece. No condenser.
Reflected Light.	*Diatoms* mounted as opaque objects. Slow plate. Four minutes. "A" eyepiece.
Dark Ground.	*Polycystina.* Webster condenser. Slow plate. Four minutes.
Polariscope.	*Brucine.* Eyepiece removed. Chromatic plate. Eight minutes.

1IN. OBJECTIVE.

Transmitted Light.	*Diatoms.* "A" eyepiece. Slow plate. Four minutes.
	Wing of Fly. Slow plate. One minute.
Reflected Light.	*Foraminifera.* "A" eyepiece. Rapid plate. Ten minutes.
Dark Ground.	*Diatoms.* Slow plate. "A" eyepiece. Sixteen minutes.
	Ditto. Ditto. No eyepiece. Ten minutes.
Polariscope.	*Aspartic Acid* No eyepiece. Chromatic plate. Eighteen minutes.

¼IN. OBJECTIVE.

Transmitted Light.	*Section of Deal.* "A" eyepiece. Rapid plate. Ten minutes.

$\frac{1}{8}$IN. OBJECTIVE.

Transmitted Light.	*Human Blood.* "A" eyepiece. Chromatic plate. Green colour screen. Thirty-five minutes.

$\frac{1}{12}$IN. OIL IMMERSION.

	Bacteria. Stained red. "A" eyepiece. No colour screen. Chromatic backed plate. Twelve minutes. Ditto, with green colour screen. Forty minutes.

When using the simple enlarging camera, fig. 5, with Ilford special lantern plates and incandescent light, an exposure of fifteen minutes was required for whole insects flattened and mounted on glass slips 3in. by 1in. (Extension of quarter-plate camera nine inches, and enlarging camera eighteen inches.) With objects stained yellow the exposure was very much increased. Many such objects are too large for low power microscope objectives.

CHAPTER VII.

REQUISITES FOR DEVELOPMENT—APPARATUS—CHEMICALS—PRICES—SUITABLE PLATES—DEVELOPERS FOR NEGATIVES—FOR LANTERN SLIDES—FOR BROMIDE PAPER—KACHIN A UNIVERSAL DEVELOPER.

Many people have the impression that the work of development must be carried on with a miserable light from a ruby lamp, and consequently inflict upon themselves trials of patience until a bad headache compels them to stop, or their powers of endurance are exhausted. Never was a greater fallacy. For ordinary plates a lamp may be used giving plenty of yellow light, so that everything can be plainly seen, and all operations carried on with comfort. Only when using chromatic plates is a red light necessary. Even with this a lamp having a large red glass front, not too deep, will give great relief, for small lamps are an abomination. In cases where a dark room is not available, the work can be done at night in an ordinary bathroom. Gas is the best illuminant, and lamps are sold that will give red, yellow, or white light at pleasure. Failing gas, the next handiest lamp is a candle lamp. Candles worked by springs are apt to be very provoking. The light sometimes either goes out or splutters

the grease all over the glass at a critical moment, and oil lamps smell and are dirty. The best all-round lamp is a canary-coloured hock bottle over a good wax carriage candle. Only good wax candles should be used; the cheap "Stearine" kind bend over from the heat and crack the glass cover.

The following apparatus and chemicals will be sufficient for a quarter-plate outfit:

Two developing dishes, with a lifter at one end to raise the plate, so that it can be grasped at the edges and lifted out for examination. This simple rocking lever fixed in the end of the tray enables one to keep one's fingers almost free from contact with the chemicals—a great boon, preventing both rough skin and stained fingers.

Two glass graduated measures.

A vertical fixing trough with six frames for plates. The advantage of the vertical position is indisputable, and as the hypo can be kept permanently in this trough, it is always ready. Any plate can be lifted out for inspection without wetting the hands.

A porcelain washing trough with grooves for twelve quarter-plates placed vertically side by side.

One ditto for lantern plates.

A print washer.

A graduated water jug.

A drying rack.

Two or three large dishes for water, hypo, and acid baths, used for bromide and platinotype prints; also one for toning if P.O.P. be used.

A hand magnifying glass.

Pins.
Mounting paste.
Weights and scales.
Funnels.
Print clips for suspending prints from a line while drying.
A dropping bottle for potassium bromide.
Six printing frames.
A printing frame for making lantern slides.
Masks and mounts.
Cover slips for lantern slides.
A knife paper trimmer.
A retouching desk.
Towels and a sponge.

The reader is advised to make his own developers. Chemicals of the kind and quantity given will be found ample for a start.

Alum	4 ozs.	at	2d. lb.
Acetic acid ...	8 ozs.	,,	2d. oz.
Citric acid	2 ozs.	,,	2d. oz.
Hydrokinone ...	1 oz.	,,	10d. oz.
Hydrochloric acid ...	10 ozs.	,,	1d. oz.
Methylated spirit ...	10 ozs.	,,	6d. lb.
Mercury bichloride ...	1 oz.	,,	4d. oz.
Metol	1 oz.	at	2s. 6d. oz.
Nitric acid ...	2 ozs.	,,	1d. oz.
Oxalic acid ...	2 ozs.	,,	6d. lb.
Pyrogallic acid ...	1 oz.	,,	11d. oz.
Potassium oxalate (neutral)	2 ozs.	,,	1d. oz.

Potassium bromide ...	1 oz.	at	2d. oz.
„ ferricyanide	1 oz.	„	3d. oz.
„ carbonate	4 ozs.	„	6d. lb.
„ metabisulphite	2 ozs.	„	3d. oz
Sodium carbonate (washing soda will do)	1 lb.	„	4d. lb.
Sodium hyposulphite	7 lbs.	„	2d. lb.
„ sulphite ...	1 lb.	„	6d. lb.
„ hydrate ...	1 oz.	„	2d. oz.

Some brands of plates have a tendency to frill and pucker at the edges, more particularly in warm weather, which, if not stopped in time, will result in the film separating from the plate. Soft gelatine or prolonged development or washing may cause it.

The best way, of course, is to reject any kind of plate that constantly gives this trouble, but it may be prevented by first rubbing the edges of the plate with a wax candle before the developer is poured on. This will keep the liquid from penetrating between the film and the glass.

The following kinds of plates will be found satisfactory:

For low powers (slow), "Castle." } (Mawson
For high powers (rapid), "Electric." } and Swan.)
For sections, "Process." (Ilford.)
For colour contrasts, "Chromatic." (Ilford.)
For lantern slides, "Special" and "Alpha." (Ilford.)

The "Special" Ilford plate gives warm and cold tones of black, and the "Alpha" gives browns and

reds. It is well to use both and have a variety of colours.

Backed plates give better negatives, but are messy, so, until the worker gains experience, it is better for him to commence with the unbacked plates.

For negatives of any kind nothing beats the pyro soda developer.

No. 1, or A.

Pyrogallic acid	...	...	60 grains
Potassium metabisulphite		...	15 „
Water	...	...	10 ounces

No. 2, or B.

Washing soda	...	...	1 ounce
Sodium sulphite	...	...	1 „
Water	...	...	10 ounces

Four drams of A and four drams of B, with five drops of ten per cent. solution of potassium bromide, are taken for a quarter-plate.

For lantern slides I find that hydrokinone is the most generally convenient. It may be made up as follows:

A.

Hydrokinone	..	...	80 grains
Potassium bromide	...	...	15 „
Sodium sulphite	...	...	1 ounce
Water	...	...	10 ounces

B.

Sodium hydrate	50 grains
Water	10 ounces

Equal parts of A and B are taken to make one ounce of developer.

Metol is the best for bromide prints, as it does not stain like some others.

A.

Metol	50 grains
Sodium sulphite	1 ounce
Potassium bromide	6 grains
Water	10 ounces

B.

Potassium carbonate ...	3 drams
Water	10 ounces

Equal parts of A and B and a few drops of bromide if necessary are taken. The metol must be dissolved first when making the solution A.

Kachin is a developer than answers equally well with ordinary plates, lantern plates, and bromide prints; and after the beginner has obtained some proficiency he may find it a convenience to have only one developer instead of three. It is rather deceptive, as it gives negatives that lose density in the fixing bath; therefore longer development is necessary.

A.

Kachin	72 grains
Sodium sulphite	350 ,,
Potassium metabisulphite ...	30 ,,
Water	8 ounces

DIATOMS.

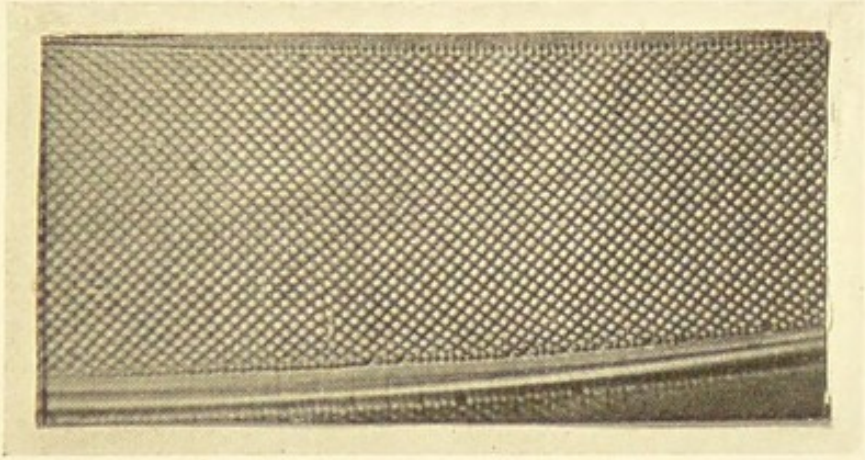


Fig. 20. Pleurosigma angulatum. $\frac{1}{12}$ oil immersion at 20in. Rapid plate. "A" eyepiece. Acetylene light. Twelve minutes.

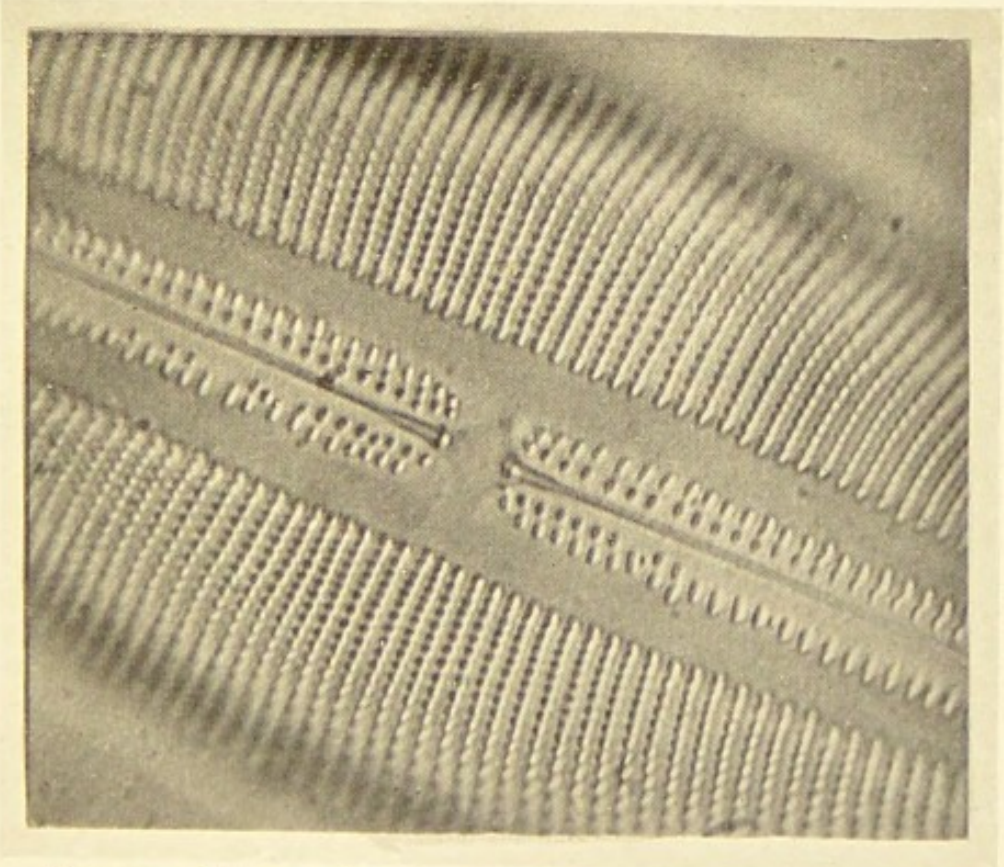


Fig. 21. Diatom showing markings. Oblique illumination. $\frac{1}{12}$ oil immersion at 20in. Eyepiece "A." Rapid plate. Ten minutes.

B.

Sodium phosphate	...	...	720 grains
Caustic soda	...	...	72 „
Water	...	...	8 ounces

Four drams of A, four drams of B, and four drams of water are taken, and a few drops of potassium bromide added if necessary.

CHAPTER VIII.

CLEANLINESS AND ITS IMPORTANCE—DEVELOPMENT — FIXING — HYPO ELIMINATORS — STORING NEGATIVES—CLEARING SOLUTION—PINHOLES —INTENSIFICATION—REDUCTION.

Cleanliness in photography is a most important item. All dishes, glasses, etc., must be well washed before being put away, so that when next used all articles will be clean. They should not be left dirty, with the idea that one will have a more favourable opportunity to tidy later on. An orderly systematic arrangement will simplify matters very much, and render operations more pleasant. Each dish should be kept for its own separate purpose.

Supposing the beginner to be only making a first attempt at development, let him place the fixing trough, lamp, developing dish, and measure containing sufficient developer for his plate, in position in readiness on a table, and then assure himself that the room is safely lighted. A jug of water for diluting the developer, if necessary, should be handy, as well as a vessel of water for rinsing the plate before fixing. If the dark room contains a sink and water tap operations are much facilitated.

All these preparations being made, the dark slide

is opened and a plate put in the dish, gelatine side up, taking care not to touch the gelatine side with the fingers. Plates must always be lifted by the edges. If the dark slide has been kept clean, there is no advantage in first brushing the slide with a camel-hair flat brush or with velvet, as the danger of leaving dust specks on the plate is as great as getting them from the dark slide. The plate should not be washed before development.

The developer must be swept over it quickly in such a way that no part of the plate is left dry, even for a moment, and the dish gently rocked to keep the solution constantly on the move all over the surface of the plate. If the developer be insufficient in quantity, dry places will be noticed on the plate over which the developer will not readily flow. This should not be allowed. The developer should be used at a temperature of about 60°. In very cold weather this is important, or the action, if there is any at all, will be slow. Boiled water that has gone nearly cold may be used, commencing with less than the full quantity of B solution, and gradually adding more if development be too slow.

A dilute developer is safest for a beginner. In half a minute or more, traces of the image will begin to appear if the exposure has been correct, and development must be continued until sufficient density be obtained. There should be no hurry. Under-development is a fault of most beginners. If the narrow strips at the edges of the plate which have not been exposed keep white no danger of

fogging need be feared. The plate may be lifted out occasionally and held up to the lamp to view the image, looking at the back of the plate also to see if the image appears at that side. If the object shows clearly and is well defined when held against the light, and also shows on the back of the plate, development may be considered sufficient.

If, however, the whole image appears thin and ghost-like, there is a fault in the exposure. Should the high lights represented by black places on the negative come up slowly and the other details do not follow, the plate is under-exposed. With patience, perhaps a printable negative may be got, but as a rule it is better to throw it away and make another. If, on the other hand, the image rushes up quickly, the plate is over-exposed, and the developer must be diluted, adding also more bromide to prevent fogging.

After development is completed, the plate may be washed in water and put into the fixing bath to stay fifteen minutes.

From this it is transferred to the washing trough, and the water changed eight times, allowing it to soak for five minutes between each change. The back of the negative is then dried with a cloth or blotting paper, and it is put into the rack to dry. The rack should be in a warm room free from dust, but not too near a fire lest the gelatine melt and spoil the plate. Slow drying will often spoil the negative by leaving various degrees of density in the film.

Flooding the plate with methylated spirit will

assist quick drying. If tap water be used for washing, it should be seen to that it is not charged with air, which causes the gelatine to separate from the glass.

Running water, where available, is more effective in dissolving out the hypo, from which the negative should be freed.

Sometimes a plate may have to be developed late at night, when it would be risky to leave it soaking in water till next day, especially in warm weather. The Hypax tabloid in such a case will be found an excellent substitute for prolonged washing. After the plate has been well rinsed it is put in a dish and covered with water. Half a tabloid of Hypax is put in one corner until all has been dissolved, the negative is then rinsed in clean water, and the hypo will have been eliminated.

A good fixing bath is made of four ounces hypo dissolved in a pint of water. Vertical fixing in a trough capable of fixing six negatives at a time is recommended. After many plates have been fixed a dirty deposit will be found at the bottom of the trough. The liquid should be examined in full light after all the holders are removed, and if it is muddy at the bottom it should be thrown away and fresh made. With this precaution the holders and fixing solution may be left in the vessel after use, so that they are always ready.

Negatives improperly exposed or developed may appear quite black and opaque when examined only

on the surface of the plate before fixing, yet after fixing will be quite thin.

Opacity should be judged by holding the negative up to the light. When washed and dried the negative may be varnished if it is likely that it will be much used, otherwise varnishing is not necessary.

A good method of preserving negatives, and at the same time of providing a ready method of selection, is to put each one in an envelope with a consecutive number outside. These may be stored in disused dry plate boxes, outside of which should be boldly printed the numbers of the slides therein. For example, the first box will be 1 to 12, the second 13 to 24, and so on.

A book index will facilitate reference. Each envelope may have also written upon it the full particulars of exposure, though this may be obtained from the exposure book. This system may be extended still further by devoting certain numbers to certain classifications. Thus all negatives of diatoms may be put in one box, insects in another, anatomical subjects in a third, and so on. The advantage is so great and the trouble so little that it is worth the doing.

When the negative has been stained yellow, and it is desired to remove this, it may be immersed in a solution of citric acid and alum—

Alum	½	ounce
Citric acid	½	ounce
Water	10	ounces

The stain is not always a disadvantage, for it may actually improve the printing capacity of the negative. After the clearing process the plate must be again washed.

Small holes or clear spots are caused by dust, and larger spots probably by air bubbles in the developer. These may be painted out with a small brush charged with colour.

Intensification is only recommended when the trouble of taking a fresh negative is too great. The photo-micrographer is in a different position from the landscape photographer, who cannot easily revisit the scene of his subject under the same conditions of light and weather, whereas the microscopist can reproduce it at pleasure.

Intensification should only be regarded as a makeshift. Mercuric chloride is a deadly poison which should be kept under lock and key, and not be brought into contact with the fingers. After the negative has been freed from hypo it may be placed in the following solution until the film becomes white :

Mercury bichloride	...	½ ounce
Hydrochloric acid	...	¾ dram
Water	...	10 ounces

It is then thoroughly washed and redeveloped with a weak solution of metol and sodium carbonate, or any ordinary developer, which will darken the film. It is again well washed and dried.

Over-dense negatives may be reduced in opacity by immersion in equal parts of fresh fixing bath

(hypo) and water and a few drops of potassium ferricyanide solution. If the reduction be too slow more ferricyanide solution may be added. The plate should be lifted out repeatedly for examination, as the action is generally rapid. It is then washed and dried.

BACTERIA.

Fig. 22. Bacillus subtilis.

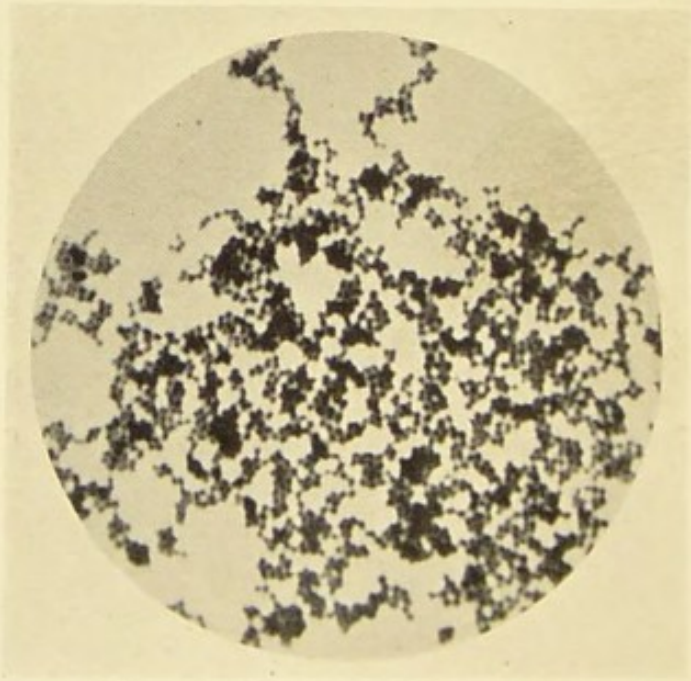


Fig. 23. Micrococcus tetragonus.

CHAPTER IX.

PRINTING ON P.O.P.—TONING—THE COMBINED BATH—BROMIDE PRINTING—DEVELOPMENT—PLATINUM PRINTING—SPOTTING PRINTS—ALBUMS.

Printing-out paper, popularly known as P.O.P., does not show microscopic objects to the best advantage. It is extremely useful for taking trial prints, however, which may be cast aside after the printing quality of the negative is ascertained. It is also in great favour with amateur photographers, who consider it the easiest process; a few words, therefore, about it will not be out of place. It is never permanent, and, although volumes are written about toning and fixing in separate processes, much trouble will be saved by adopting a single solution for both fixing and toning. The great advantage of this paper is that the result can be seen and printing stopped at the right moment.

The paper is laid on the negative, glossy side of paper in contact with film side of negative, and placed in a printing frame for exposure to daylight, though not to direct sunlight unless with very dense negatives. The print should be slightly darker than the finished print is intended to be, owing to loss of colour in fixing.

The handling of the paper and inspection of prints should be done in subdued light. After printing is completed, the paper is put in a combined toning and fixing solution until the desired tone is obtained, and then is washed thoroughly in running water, or by eight changes of water, allowing five minutes soaking between each change. Every maker of paper issues full instructions with each packet, but, as nearly all differ, the reader should buy a bottle of combined fixing and toning solution from any photographic dealer, and simply wash his prints well after they come out. If the reader desires to prepare his own solution, the following formula may help him:

Ammonium sulphocyanide ...	15 grains
Table salt	30 grains
Hypo	2 ounces
Water	10 ounces

To this one grain of gold chloride in half an ounce of water is added.

The little clips similar to clothes' pegs are useful for drying the prints. The paper is gripped at one corner and suspended from a line until dry. Printing frames should have open ends to enable the paper to be raised for examination with ease when the half back is folded over on its hinge. Some cheap frames have a deep recess, into which the negative and paper drop as into a box, making it extremely difficult to inspect the process of printing without creasing the paper in the endeavour to

raise it. A mask with an opening of a suitable size and shape placed between the negative and the paper will give a neat finish to the print.

Bromide paper is the quickest for microscopic work, and can be done by gaslight. It gives a contrast of velvety black and white, but the picture is not visible after exposure until developed. More uniform results may be obtained from artificial light than from daylight, if several prints are to be taken from one negative, because the correct exposure, having once been ascertained, can be repeated.

The Velox carbon matt is especially suitable for the purpose, being a slow paper capable of development without a dark room lamp and in fairly full gaslight. This is a great relief to the eyes, avoiding, as it does, the fatigue caused by frequent alternations of bright light for exposure and comparative darkness for development, when quick papers are used. In any case, all the negatives to be printed from should be put in separate frames and the exposure made before lowering the light. When held flat in the hand, bromide paper will curl slightly with the sensitised surface inside. Wetting the corners with the thumb and finger in order to distinguish the different sides is not a clean habit. The exposure depends on the negative, but for average density the Velox carbon takes twenty seconds at six inches from a No. 5 burner. A thin negative should be held further away from the light; a dense one, nearer. The frame is best kept between the eyes and the gas to shade the eyes

during exposure, and if frequent exposures are made at one time, neutral tint spectacles during the time the light is full on will be found a relief. Having made the exposure and lowered the light, the paper is taken from the frame and dipped into clean water, so that it will lie flat in the developing dish. The developer is swept over the paper, keeping it freely on the move until the required depth of tone be reached, when the paper is rinsed in clean water and immersed edgewise, face up, in the fixing bath made up as follows:

Hypo	... ...	4 ounces
Water	... ...	16 „

To this are added—

Sodium sulphite	... ...	1 dram
Acetic acid	... ...	6 drams
Alum	... ...	1 dram

dissolved in one and a quarter ounces of water.

The prints are kept moving a few moments, and afterwards allowed to remain fifteen minutes. An hour's washing in running water or in eight changes of water, as before described, completes the process. A thorough washing should be given. The above bath keeps clean much longer than a simple hypo and water bath, and can be used time after time.

Platinotype printing is at once the simplest, most permanent, and most effective of all processes. Good negatives yield prints equal in beauty to a fine steel engraving, with rich gradations of tone very pleasing to behold. The whole process can be

completed on a bright day in a little over an hour, though on dark days the printing is slow. Moisture is the chief preventive of successful work; therefore paper, wood frames, and place of exposure must be dry.

The platinotype paper itself is supplied in sealed tins, twenty-four sheets, quality A.A. 4¼in. by 3¼in. for 1s. 6d., from which it should be removed for preservation to a special tin tube having a false bottom, under which calcium chloride is kept to absorb any moisture, and the joints of this tube are further protected by a wide rubber band. Thus protected, the paper will keep in good condition many months. The lemon coloured surface of platinum paper is more sensitive to light than is that of P.O.P.; consequently, the placing of the paper in the frames, the examination of prints, and developing must be done in dull light. After the sheet of platinotype paper is put on the negative it is desirable, though not essential, to add a protecting sheet of rubber or waterproof paper before fastening the back of the printing frame. During exposure, which must be by daylight, an occasional peep at the paper will show how far printing has proceeded. The image is only faint grey when finished, but every detail should be seen, however feeble. If there be any part of the print that should be pure white when finished, the attention should be fixed on that spot, and its tint compared with that of the edges of paper. So long as this is the same lemon colour it may be gathered that printing is not car-

ried too far. As development is very rapid, the exposure must be correct to get good results. After a few trials it will not be found at all difficult to determine when to stop printing. The developing bath, which should not be below 60° F., is made up of:

Neutral potassium oxalate ... 1 ounce.
Oxalic acid (saturated solution)
1 part to 20 parts of developer.
Water ... ... 10 ounces.

This is a stock solution, and may be bottled for future use. The paper is floated on the bath face downwards, turned quickly over and development watched. A black and white image will rapidly appear, and when sufficient depth of tone is obtained the print may be removed to a bath composed of:

Water ... ... 10 ounces.
Hydrochloric acid ... ... 1½ drams.

Any of the lemon colour left will here be cleared away, and black and white tones only remain. After five minutes in this bath the prints are transferred to a similar but rather more dilute bath for ten minutes; then to three baths of clean water for ten minutes each, into the second of which a few grains of sodium carbonate have been added to neutralise any acid left in the prints.

Wollf's "indelible railway pencil" is excellent for any retouching with either bromide or platinotype prints. Photo-micrographs kept in a special album having only one print on a page show to better advantage than when mixed with others of a miscellaneous kind.

CHAPTER X.

Lantern-slide Making—A Slide-making Frame.

Lantern slides, if well made, give pleasure to young and old, whilst their educational value is universally acknowledged to be of great importance. They no longer remain the monopoly of the travelling entertainer, since slides are now produced by almost every scientific society. Equally helpful are they in the private house where one who has learnt how to make them may enjoy many a winter evening, even with only himself for audience. To one who has mastered the art of negative making no difficulty will be experienced, for the developing of lantern slides is similar, except that a positive image appears, instead of a negative. This fact renders it much fuller of interest, as the gradual unfolding of the complete image never fails to delight the operator. The standard size for English slides is 3¼in. by 3¼in., a suitable size for contact printing from a 4¼in. by 3¼in. negative.

The usual slide-making frame consists of a board having a 3¼in. square hole in the centre, into which the sensitised plate fits. The negative is placed film side to this hole, and is held against the cloth-faced board by springs in such a way that the negative may be moved in any direction to bring the

right position opposite the centre. The dry plate is then put on and covered with a wood block the same size, which again is pressed by a spring to keep the negative and plate in contact.

The exposure varies with the plate used. "Ilford Special" lantern plates for warm and cold tones require twenty seconds at eighteen inches from an ordinary gas bat's-wing burner. "Ilford Alpha," for red and brown tones, two minutes at six inches from a fish-tail burner. Development and fixing are the same as for negatives. The least fogging of the lights, it should be noted, will spoil the slide, and the image must stand out well defined on a perfectly transparent background. Spoiled plates make good cover glasses, if stripped of gelatine by steeping in boiling water and soda. When the plates are ready for mounting, a square or circular mask is placed between the cover and picture. If there is room on the margin of the mask, which is usually black, the title may be written upon it with white ink, not forgetting to put a white spot in each top corner when looking at the picture the right way about. These are for the guidance of the lanternist who puts the slide into the lantern upside down with the spots towards the condenser. Nothing is more awkward for both audience and operator than pictures projected in a wrong position.

APPENDIX.

USEFUL BOOKS.

Title.	*Author.*	*Publisher.*	*Price.*
Photo-micrography ...	E. J. Spitta	Scientific Press	12/6
(This is decidedly the best book for the professional man and the advanced worker.)			
Atlas of Bacteriology ..	Slater & Spitta...	Scientific Press	7/6
Photo-micrography... ..	Pringle	Iliffe & Sons Limited	5/-
Photo-micrography	Jenning	Piper & Carter	3/-
Photo-micrography	Bousfield	Kent & Co	1/-
Ditto.	(larger edition)		6/-

Chapters on photo-micrography will also be found in some of the following handbooks on the microscope—

Methods of Microscopical Research	Cole	Baillière, Tindall & Cox...	6/-
Practical Microscopy...	Davis	Allen & Cox	7/6
The Microscope	Van Heurck	Crosby Lockwood	18/-
Popular Handbook to the Microscope	Wright	Religious Tract Society...	2/6
The Microscope and its Revelations	Dallinger	J. & A. Churchill	28/-
The Microscope	Hogg	Routledge	12/6
Modern Microscopy ...	Cross & Cole	Baillière, Tindall & Cox	3/6
Common Objects of the Microscope	Wood	Routledge & Sons	3/-
Half-hours with the Microscope ...	Lankester	W. H. Allen & Co.	1/-
One Thousand Objects for the Microscope...	Cooke	Warne & Co.	1/-
Micrographic Dictionary	Griffith & Henfrey	Van Voorst	52/6
Evenings at the Microscope	Gosse	Christian Knowledge Society	

BOOKS ON PHOTOGRAPHY AND OPTICS.

Optical Projection	Wright.....	Longmans Green	
Light	Wright	Macmillan	
Instruction in Photography	Abney	Piper & Carter	/6
Barnet Book of Photography		Elliott & Son	1 -
Photography in a Nutshell	"The Kernel"...	Iliffe & Sons Limited ...	1/-
Lantern Slides. How to Make Them	Dresser	.....	6d.

LIST OF PLATES.

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EXPOSURES.

POWER USED.	EYE-PIECE.	MODE OF ILLUMINATION.*	PLATE.	OBJECT.	CHARACTERISTIC.	DISTANCE OF OBJECT FROM SCREEN.	EXPOSURE.	RESULT.

*Under the head of Illumination the following abbreviations may be used: T, for transmitted light. R, reflected light. D, dark ground. O, oblique illumination. P, polariscope.

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