The Book of The Watson Microscope

W. WATSON & SONS Ltd.
LONDON

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Being Directions for the Use
& Preservation of Microscopes

Manufactured by

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INTRODUCTION.

The purpose of this booklet is not in any way to replace the excellent textbooks and manuals that are published in connection with the Microscope and microscopical manipulation. Its aim is to give plain directions to the novice so that he may from the first use his microscope in an intelligent manner and become acquainted with such constructional details of the instrument itself as will give him confidence and, at the same time, induce him to treat the parts from which such strict accuracy is demanded, with the care necessary to secure maximum working efficiency for a lengthened period.

We would add that it is always a pleasure to us to give any advice that lies in our power in connection with microscopical work generally, and our own instruments in particular, for it is only as a worker appreciates the possibilities and excellences of his instrument and obtains the finest results that can be yielded by both the optical and mechanical parts that the fullest satisfaction is obtained and the perfection of our microscopes is properly appreciated.

Our best services are always at the disposal of our customers.

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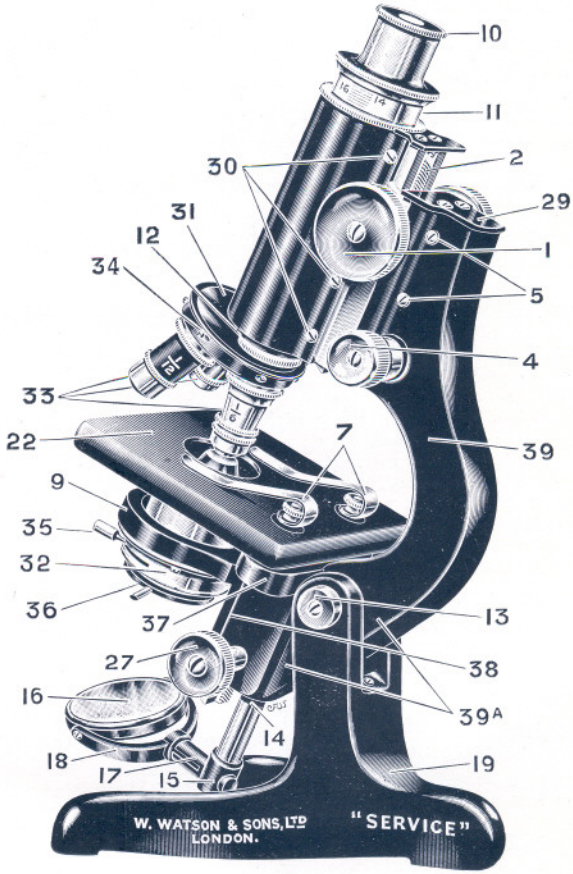


Fig. 1. **The "Service" Microscope.**
See description pages 4-5.

DESCRIPTION OF VARIOUS NUMBERED PARTS OF MICROSCOPES.

Illustrated on pages 3 and 6, Figures 1 and 2. Unless otherwise marked the same numbers refer to Figures 1, 2 and 4.

1 Milled heads attached to pinion of coarse adjustment.
2 Rackwork which engages the pinion for coarse adjustment.
3 Screws for adjusting tension of coarse adjustment pinion.
4 Milled head controlling fine adjustment.
5 Screws for taking up wear in fine adjustment fitting.
6 Fulcrum of lever of fine adjustment (Fig. 2 only).
7 Stage springs.
8 Aperture for fitting stage forceps, side silver reflector, etc. (Fig. 2 only).
9 Rackwork underfitting (Fig. 1 only).
10 Eyepiece or ocular.
11 Drawtube.
12 Female thread by which objectives or nosepiece are attached.
13 Axis joint for inclination of the Microscope limb.
14 Tail-piece carrying mirror.
15 Mirror fitting.
16 Mirrors.
17 Mirror arm.
18 Mirror gymbal.
19 Foot.
20 Reader for fine adjustment (Figs. 2 and 4).
21 Divisions on fine adjustment milled head (Fig. 2).
22 Stage (Fig. 1) plain.
(Fig. 2) built-in mechanical form.
23 Milled head controlling vertical movement of mechanical stage (Fig. 2).
24 Milled head controlling horizontal movement of mechanical stage (Fig. 2).
25 Compound centring substage (Fig. 2).
26 Screws for centring the condenser in substage to optical axis of the microscope.
27 Milled head controlling rackwork for raising and lowering substage (Fig. 2).
28 Compensating spring slots on fine adjustment.
29 Plate covering spring box of fine adjustment.
30 Screws for taking up wear in coarse adjustment fitting (Fig. 4).

31 Revolving triple nosepiece carrying three objectives (Fig. 1).
32 Abbe Illuminator, understage type.
33 Objectives.
34 Tangential centring screws on nosepiece.
35 Arm controlling iris diaphragm of condenser.
36 Carrier for colour screens or dark-ground stops of condenser.
37 Part of bracket carrying stage (Fig. 1).
38 Bearing of limb to carry alternative substages (Fig. 1).
39 } Optical bench limb, carrying all movements of Mi-
39a } croscope upon which the optical parts are mounted.

UNPACKING.

It is desirable that before removing the microscope from its case, the manner in which it is fitted should be noted, so that no difficulty may be experienced in replacing it.

The several items of the consignment should then be carefully checked to see if everything is included.

Careful inspection should be made to ascertain that no damage has occurred in transit.

TO SET UP FOR USE.

The first thing to decide is whether an artificial illuminant shall be employed or daylight.

Daylight.

The majority of workers find it inconvenient to work by daylight, and it is objectionable for more than one reason. In the first place, the light is not of a constant quality, and in the next—in order to obtain the finest effects with the microscope—it is necessary that the light in the room should be, as far as possible, confined to that which illuminates the microscope only, so that the worker himself is practically in the dark.

If daylight is used, a window facing north is generally to be preferred, and the best illumination is obtained from white clouds. Direct sunlight must be avoided.

Artificial Illumination.

Oil.—For visual work, no light is superior to the lamps regularly sold for microscopic work, having usually a $\frac{1}{2}$-in. flat wick. When such a lamp is employed, the flat of the flame is used under all conditions other than when a substage condenser is employed.

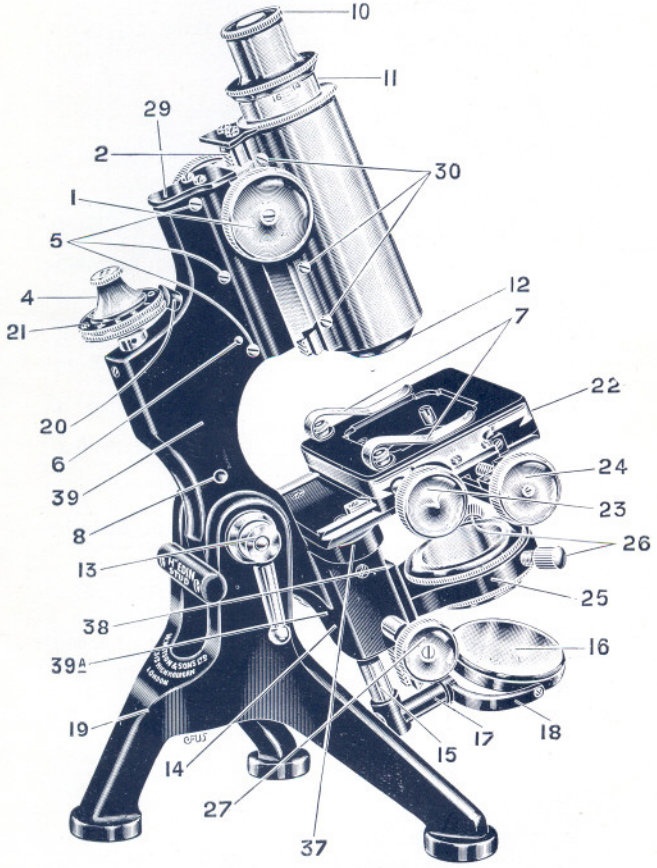


Fig. 2. **The " H " Edinburgh Student's Microscope.**
See description pages 4-5.

Electric Light.—In the majority of laboratories and for routine, as distinct from research, work, the electric lamp will be found advantageous. Special lamps for microscopical work have been introduced recently. The most useful form is the " Pearlite " bulb mounted in a metal hood, which prevents direct light reaching the eye of the observer, thus eliminating the fatigue due to varying intensities of illumination. These will be found generally useful, but for critical illumination cannot be regarded as best when the resolving power of the objective is to be tried to its utmost capacity.

(Special attention is drawn to the " Service " lamps for laboratory and routine work—the Projector and Universal lamps for all-round microscopical work.)

We will now proceed **to set up the microscope** with a **Low-power Objective.**

It will be well first of all that an acquaintance be made with the direction of movement produced by turning the milled heads. The milled heads of both coarse and fine adjustments (Nos. 1 and 4), when turned clockwise, bring the tube nearer the stage 22.

The object is placed on the surface of the stage No. 22 in the illustration, beneath the spring clips, No. 7.

One of the objectives is removed from its box and screwed into the lower end of the microscope body at the part marked 12, or if a nosepiece is used, into the nosepiece thread.

One of the eyepieces is inserted at the upper end of the body, at No. 10.

The body should be racked downwards by means of the milled heads No. 1, until the front of the objective almost touches the object, and as far as possible the object that is to be viewed should be set immediately under the objective.

The mirror No. 16 should then be so set as to receive light from the illuminant and direct it to the object on the stage. For this purpose it may be necessary to slide the fitting No. 15 on the tail-piece 14, and the gymbal ring 18 should be turned on the arm 17, care being taken that the light when reflected up the tube follows the path of the optic axis; this can be checked in racking up to focus the object. If the light is axial the magnified object will remain stationary, but if the light is oblique the object will appear to travel in the direction of the light.

Very gently rack the body upwards by means of the milled heads No. 1 until the object comes into view. Then to get the sharpest possible definition, the fine adjustment milled head No. 4 may be turned.

It may be that in racking the body tube upwards the object does not come into view in consequence of its not being exactly beneath the objective. In such a case, it will be best to rack the body down again to the point from which it started and then very gradually raise it, watching to see if any specks come into the field. The appearance of anything of this kind will indicate that some slight defect on the object slip has been focussed, and it will then only be necessary to move the object on the stage surface until it comes into the field of the optical system. A very small amount of practice will render the user proficient in doing this.

If the observer is unable to locate the object successfully, this may be done by removing the eyepiece and looking at the back lens of the objective, where the object may be observed.

Extra Low-power Objectives.

In order to use objectives of 3 inches and 4 inches focus, for which in microscopes of compact builds there is sometimes not sufficient rackwork adjustment, we include a fitting carrying the standard size of screw for objectives at the lower end of the draw-tube. These objectives should be attached to the screw, which is accessible by unscrewing the collar in which the draw-tube slides. This screw will be seen in the diagram on page 18.

High-power Objectives.

With high-power objectives, assuming that no substage condenser is used, the same procedure would take place as with the low-power objectives, excepting only that the front of the objective would have to be made to actually touch the object before racking upwards, and a greater amount of accuracy is necessary in setting the object in the field, on account of the increased magnification. As the working distance of high-power objectives—from 1/6″ upwards—is very short indeed, the front lens being at most 1 mm. from the object, it is necessary that subjects under observation be covered with thin " cover " glass.

In Watson Microscopes the objectives are parfocalled,

and if the object is in focus with the low power (2/3″) objective, it will be found to be in focus within one turn of the fine adjustment when the high-power objective is brought into position.

THE SUBSTAGE CONDENSER.

In order, however, to develop the full capacity of the microscope, it is essential that a substage condenser be employed. This, in the case of a Student's microscope, fits into the underfitting No. 9 in Figure 1 ; or, in the case of a microscope having a compound substage, into the fitting No. 25 in Figure 2. In the former instance, the tube is already set central before the microscope leaves the Works, but latitude is allowed for resetting by slackening the screws by which the tube flange is attached to the bracket, which latter has slots to permit of movement. Generally speaking, however, this should only be done by experienced workers.

Important Notice.

The condenser is racked upwards in substage No. 9 (which is of the Royal Microscopical Society's standard gauge) until the upper surface of the top lens comes flush with the stage surface. This can be exactly arranged by placing an object on the surface of the stage and holding it firmly, and adjusting the condenser until the desired position is attained.

The optical part of the condenser is mounted on a separate sliding tube within the mount, and can be raised in its sleeve to the level of the stage surface, if a mechanical stage of the " Service " type is fitted later.

If the microscope has a substage, as in the illustration in Figure 2, the condenser is inserted in it and the rackwork employed to carry it up to about level with the surface of the stage. It is then necessary to see that it is central with the objective. It should be explained that differences of centres occur with objectives, especially if they are by different makers, and the only way to secure the maximum effect from a condenser is by carefully centring it in the substage.

To centre the Condenser.

(a) When using low-power objectives, say 1″ or 2/3″ There are two ways in which this can be done—

1. By putting a mark on the upper surface of the top lens of the condenser.
2. By using the Iris diaphragm at the back of the optical part for the purpose.

Process 1 is the best with the Abbe Illuminator. A very small spot of ink should be set as nearly on the centre of the top lens as possible. This should then be viewed through the microscope as if it were an object, and the centring screws No. 26 turned until it occupies the centre of the field. The spot can then be wiped off.

With achromatic condensers a 1″ or 2/3″ objective is employed ; light is thrown through the condenser, and the Iris diaphragm closed down to its smallest aperture. The objective should then be very slightly racked upward, it being necessary to focus and centre the aerial image formed by the diaphragm through the lens of the condenser. This generally lies in a plane about $\frac{1}{8}$″ above the surface of the condenser lens. This is not easy to do at first, but with a little practice facility will be attained.

When the centring has been accomplished, the low-power objective is removed and the high-power interchanged.

If at any time it is desired to check the centring of the condenser when using high-power objectives, the eyepiece 10 can be removed and the back lens of the objective examined by looking down the tube of the microscope. If, then, the Iris diaphragm of the condenser be gradually opened and closed, its centrality can be verified.

To Focus the Condenser.

The condenser requires not only to be centred, but also to be focussed in the plane of the object that is under examination, and this should be as accurately done as with the objective. The larger the aperture and the higher the power of the condenser, the greater is the accuracy of manipulation required.

As a general guide, however, it may be stated that the Abbe Illuminator, Universal Condenser, and similar condensers are about in focus when the front lens is approximately 1/25th inch from the under-side of the object, this distance varying with the thickness of the object slide and the distance of the illuminant.

The method of focussing is as follows :—

Using the plane mirror and the edge of a lamp flame as the source of light, the lamp is set about 4 inches from

the mirror. The light is then directed through the condenser, the upper surface of the lens of which is to be in contact with the under-side of the object.

The object itself is then sharply focussed with the objective. The condenser must then be moved downwards until the image of the lamp flame appears in the field as a bright central streak between two dark margins similar to illustration, Fig. 3.

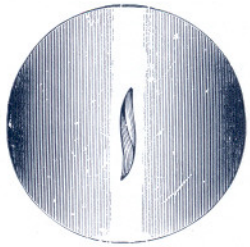


Fig. 3.

Image of Lamp Flame, with object in position, when Condenser is focussed.

When doing this, the Iris diaphragm should be almost entirely closed.

For critical work, the illumination thus obtained—the aperture of the Iris diaphragm of the condenser being adjusted to the most suitable diameter—is the most effective that is possible, it being borne in mind that every objective of medium or high power gives its best definition at one point of the field only, and when working critically everything is sacrificed for that best effect in the centre of the field.

For some studies it is desirable to have the whole of the field illuminated. In such circumstances, a bull's-eye may be interposed between the lamp flame and the mirror, or the flat of the wick may be turned round and its surface used instead of the edge.

As critical illumination is rarely used in the work for which a microscope is more generally required, viz., for identifying and searching for known structures, the Electric Lamp before referred to should be set as

described for the Oil Lamp, and the condenser focussed to the point of greatest intensity.

The effective aperture of the objective is only utilized in proportion to the size of the cone of light yielded by the condenser, so it follows that the Iris diaphragm of the condenser must be suitably opened. The flood of light is then frequently too great to be comfortable. Under such conditions a coloured glass screen should be used. For general work it will be found advantageous to employ a light blue glass disc in the condenser to neutralize the yellow colour of the oil or electric lamps.

So much can be ascertained by the study of the back lens of the objective that it is desirable that the microscope worker should early become acquainted with the phenomena there represented. Textbooks on the microscope give a vast amount of information on this subject. Our present object in calling attention to this is to point out that the size of the cone of light which is being utilized by the objective may be at once judged by such an examination.

When the microscope is adjusted for working, the eyepiece is removed and, on looking down the tube, the bright appearance of the back lens of the objective will be seen. Generally speaking, not more than three-quarters of this back lens should be filled with light. Very few, if any, objectives will bear more than this advantageously, with respect to definition, etc. The amount of illumination necessary varies so much with different objects that may be examined, that familiarity with this method of working is the surest and most accurate means of securing the best and most uniform results. It should be noted that the eye must be placed close to the upper end and accurately centred to the tube during such examinations of the back lens, otherwise an entirely wrong result may be obtained.

The increasing recognition of the advantages to be derived from the use of a well-corrected Achromatic Condenser in preference to the ordinary Chromatic type suggests that a few hints should be given on this point.

The modern Objective will not work advantageously with more than a $\frac{3}{4}$ cone of illumination—i.e., if the eyepiece be removed and the condenser focussed the back lens of the objective should be evenly illuminated with

a circle three-quarters of its diameter, when axial illumination is used. It will be obvious at once that there must be some relation between the condenser's illuminating power and the effect at the back of the objective to produce this result. Both of these effects depend on essential features—the condenser on its aplanatism, and the objective on its numerical aperture. The value of the condenser does not depend so much on its total numerical aperture as on its correction for aplanatism which imparts the quality of aplanatic or solid cone illumination.

The ordinary Abbe Illuminator has an aplanatic cone of about ·5 N.A. It is therefore fully effective for central illumination with objectives having a total numerical aperture of 65, and this is sufficiently near for the great bulk of work that is done with the $\frac{1}{6}''$ objective of approximately this numerical aperture.

When, however, an Oil Immersion Objective is used, its effects are limited by the aplanatism or want of aplanatism of the condenser, and so far as the revelation of fine detail is concerned, very little more is discernible than with the $\frac{1}{6}''$. In fact, a better quality, more perfectly corrected condenser should be used with a 1/12″, to obtain from it the results which it is capable of yielding.

The importance of a well-corrected condenser will be recognised by the statement that effective working is ascertained by adding together the numerical aperture of the objective and the aplanatic cone of the condenser. Taking the Abbe Illuminator as the basis, with the ordinary Oil Immersion Objective of 1·30 N.A., i.e., ·50 + 1·30 = 1·80, divided by 2 gives ·90 as the effective aperture of the objective. If a condenser with an aplanatic aperture of ·95 were used, such as the Universal, the result would be 1·30+·95=2·25, divided by 2=1·12, an increase of efficiency of about 20 per cent.

There should also be a proper relationship between the power of the condenser and the objective, and for this purpose the higher power condensers are usually designed to have the upper lens or lenses removable by unscrewing the cells when lower powers and less numerical apertures are required. See table in Catalogue, Parts 1 and 2, showing apertures of different condensers with the top lenses removed.

Dark-ground Illumination.

For Low Powers.—Certain objects are of so transparent a nature that their structure is not disclosed when ordinary transmitted light is used. By placing a black patch stop beneath the back lens of the condenser, the object stands out clearly upon a black background in a charming manner.

This method of illumination is particularly applicable to pond-life subjects, etc., when examined with low powers—say up to $\frac{1}{2}''$.

Owing to the shortness of focus of the ordinary substage condensers, difficulty is often experienced in illuminating objects contained in troughs, etc., with a black background.

A spot lens, on account of its long focus, will therefore often be found more suitable.

For High Powers.—The **"Holos" Immersion Paraboloid** produces dark-ground illumination with high-power objectives. Its particular usefulness lies in the searching for and examination of living bacteria, especially Spirochæte, for which a high-power objective is necessary. Generally no objective having a numerical aperture in excess of 1·0 can be used for dark-ground illumination, and as the 1/12th inch Oil Immersion lens is generally preferred, its numerical aperture is reduced by placing a diaphragm of funnel shape in the interior of the mount of the objective. Recently the Watson 1/7th inch Oil Immersion Objective with a numerical aperture of less than 1·0 has been found to meet all requirements with a saving in equipment and cost, for such a lens may take the place of both 1/6th inch and 1/12th inch Oil Immersion for objectives. The "Holos" Immersion Paraboloid is sometimes referred to as an "Ultra" Microscope.

The special conditions necessary for working are given in Watson's full catalogue, but may be summed up in **absolute centrality of condenser with objective,** for which a centring rackwork substage is essential; proper thickness of object slip as indicated on the paraboloid; the paraboloid must have a film of oil between its top lens and the under-side of the object slip, and the oil contact must be maintained. There is no comparison in the accuracy of the result obtained when using a centring substage as compared with the centring nosepiece.

Nelson's Cassegrain Condenser.

This Cassegrain Dark-ground Illuminator has the advantage over all other dark-ground illuminators that it can be used with the full aperture of any objective, without the insertion of the funnel stop.

This means that the efficiency of an Oil Immersion lens of 1·30 numerical aperture can be fully employed, while with other dark-ground illuminators the maximum aperture that can be utilized is 1·0 N.A.

The method of use is generally the same as with a "Holos" Immersion Paraboloid, the necessity for absolute centration being emphasized on account of the larger numerical aperture and greater sensitiveness to exact adjustment.

It is not always easy to maintain immersion contact between the large surface of the top lens and the under-side of the slide, and some more viscous material is generally recommended than ordinary immersion oil. Golden syrup has been found to be an excellent substitute.

Fuller particulars for working this are contained in the description of it in the catalogue.

Revolving Nosepiece.

With the majority of microscopes a nosepiece carrying 2, 3 or more objectives is provided, so that examination may be made rapidly with objectives of different power. When this is fixed in position on the microscope by means of its screw collar, it should be finally clamped with the projecting part exactly outwards in a line with the body towards the front of the stage. It must not lie on either side, otherwise, when the tube is racked upwards, it will foul the bearing slides.

The revolving nosepiece requires to be treated with great consideration. A moment's thought will reveal the accuracy that is demanded, and the least strain will tend to make it incorrect. Watson Nosepieces are engraved with an arrow showing the direction of rotation, and **this must** be strictly adhered to. The nosepiece apertures are provided with tangential centring screws which are accurately adjusted for each objective when the instrument is despatched. Thus an object lying in the centre of the field with a low-power objective will be found within an area of half the radius of the field when the low-power objective is replaced by one of higher power.

OBJECTIVES.

Magnifications.

A list of magnifications is given on page 31, but a table showing the magnifying powers of the objectives and eyepieces accompanies every Watson microscope. Further details are to be found in the full catalogue, but the magnification can always be roughly ascertained by remembering that it is secured by the eyepiece in conjunction with the objective, it only being necessary to multiply their powers together.

It may further be remembered that the designation $\frac{1}{2}''$, $\frac{1}{4}''$ $\frac{1}{6}''$, etc., does not represent the working distance of objectives, but the equivalent focus, on which the magnifying power chiefly depends; the 1″ objective magnifying approximately 10, the $\frac{1}{2}''$ 20, the $\frac{1}{6}''$ 60, the 1/12″ 120 diameters, and so on. All the eyepieces are engraved with a figure denoting their magnifying powers. Supposing a No. 2 eyepiece with a power of 6 were used with a $\frac{1}{6}''$ objective, the magnification yielded would be approximately $6 \times 6 = 360$ diameters. This is reckoning for a 10″ tube length; if a longer or shorter tube length is used, the proportion is greater or less. Ten is made the denominator, the tube length employed the numerator, and the ascertained figure referred to above is multiplied by this fraction; thus—with a No. 2 eyepiece and $\frac{1}{6}''$ objective at 8 inches, the magnification would be, roughly, $360 \times 8/10 = 288$ diameters.

It will be noted, on reference to the catalogue, that the powers of the objectives are not absolutely exact to the rule stated, but the above is given as a method of rough calculation.

Flatness of Field.

This is mentioned especially to point out that this feature cannot exist in any other than low-power objectives, and the fact applies to objectives by all makers. We are so often asked if we can supply high-power objectives with a flat field that we have thought it well to call special attention to this matter.

Theoretically and practically, all microscope lenses have a curved field, and with high-power objectives the greater the excellence of the lens, the more particularly does this become apparent. It is possible, by altering the focus, to view separately every zone of the field, but when a specimen is focussed in the **centre** of the field,

this part only is absolutely sharp. Flatness of field can only be obtained by sacrificing the maximum sharpness at the focal point, and this produces inferior definition. The necessities of many classes of work render desirable as great a degree of flatness of field as can be discreetly given, and the judicious combination of that effect with the best possible definition in the circumstances is provided.

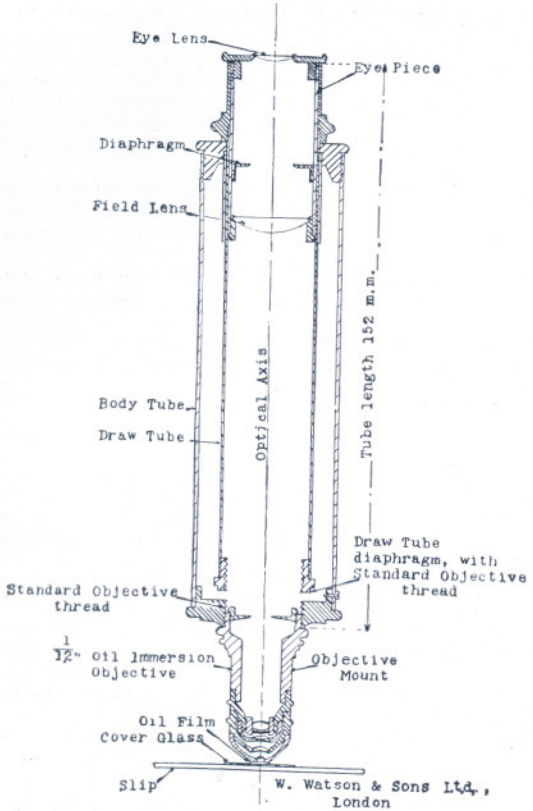
It is possible to give an appearance of flatness of field by a reduction in the diameter of the eyepiece diaphragm, but this limits the area observed and the full value of the objective is not obtained.

With low powers—1″, $\frac{1}{2}''$, $\frac{2}{3}''$, etc., and those of less magnification, flatness of field can be secured over nearly the entire surface, but under no circumstances can flatness of field be produced in a lens of large aperture and **fine quality** of high power—it is an optical impossibility.

Resolving Power.

The power to define fine detail in an object is dependent on the angle of the bundle of rays which it is capable of receiving from the object. This quality is expressed by the term "Numerical aperture." The higher the numerical aperture, therefore, of the objective that is employed—subject to its being of good performance—the greater will be the power to resolve fine structure. It must be remembered, however, that with the increase of numerical aperture, the working distance of the lens is shortened; in all our lenses the ratio of numerical aperture to the power has been very carefully considered and established.

The working distance depends not only on the focal power of the objective, but also on its numerical aperture. The greater its numerical aperture, the more closely it must approach to the object when working. Students and others who work in laboratories frequently use a variety of cover-glasses of varying thicknesses, and we recommend, especially when a $\frac{1}{6}''$ objective is chosen, that the one in our list with a numerical aperture of ·70 should be purchased in preference to the one of larger aperture for this very reason. The former will work through the cover-glass of a Hæmacytometer, while the latter will not.



Sectional view of the body of a Watson Microscope with Eyepiece and Objective in position.

The above diagram is to show the method of measuring body tube length. Watson Microscopes, with the exception of the " Royal " and " Van Heurck " series, are engraved on the draw-tube to show the tube length, including the revolving nosepiece.

Oil Immersion Objectives.

With certain high-power lenses, a film of special immersion oil, which is supplied with the lens, is interposed between the cover-glass of the object and the front lens of the objective, continuity of the light being established thereby. This oil is approximately of the same refractive index as the cover-glass itself, and the practical effect of the oil is to admit light which could not possibly enter a dry objective, for the oil prevents the spreading out by refraction of the rays emanating from the object which would occur when passing from the cover-glass—which has a high refractive index—to air, which has a lower refractive index. Such rays are, as the result of the oil film, utilized by the objective.

The immersion objective requires to be carefully treated. In cold weather it often happens that this oil, which normally is quite clear, becomes cloudy ; this may generally be cleared by warming, but if it still persists, it is best to pour off the upper portion and throw away the residuum.

IMMERSION OIL.—It is of the utmost importance that the Immersion Oil supplied by Watson's with their Oil Immersion Objectives should be used with them, and none other.

If such an objective is used with an oil which is not of the refractive index or dispersion for which the lens has been corrected, the efficient working is seriously impaired. Many of these immersion oils are injurious to the objectives themselves, and cause the displacement of the front lens, by acting as a solvent on the cement which holds them.

To get the best effects the immersion oil supplied by Watson's should be used with Watson's lenses.

The oil should be wiped from the front of the immersion lens immediately after use. If by any chance a small quantity of oil should become dried on the front lens, it should be treated very gently. The readiest and easiest method is to put a quantity of fresh oil upon it and let that act as a solvent on the dry deposit, then wipe the whole off together. If necessary, repeat the process two or three times. A quicker method is to soak a piece of very soft cotton rag or clean silk with xylol and gently wipe the front with this.

It has been recommended that for the entire removal of oil immediately after use saliva should be used. This has proved very effective. **Care must be taken to clean the margins of the lens.**

Thickness of Cover Glass and Tube Length.

These are important factors in obtaining the best results from objectives. If an objective is corrected for a definite tube length with a stated thickness of cover-glass, it will work at its best when so used. If a greater or less tube length be employed, with the same thickness of cover-glass, the effect will be marred to a greater or less extent. The method of measuring the body length is shown in diagram on page 18.

If, however, the tube be set at the length for which the objective is corrected, and the cover-glass be of a different thickness from that which is prescribed, the resulting definition is not the best possible. This can then be overcome by varying the length of the draw-tube, making the total length of body shorter if the cover-glass is thicker, and the total length of body greater by extending the draw-tube if the cover-glass is thinner than that for which the objective has been corrected. It requires a certain amount of experience and training to detect the subtle differences in definition, but when once acquired, the draw-tube is either extended or pushed inwards with unerring rapidity until the best definition that is possible is secured.

The **Mechanical Draw-tube,** actuated by rackwork and pinion, enables the correct length of draw-tube to be determined to a nicety, and is a valuable addition to a Research Microscope. See Catalogue, Parts 1 and 2, page 43.

It should be mentioned that oil immersion lenses are not so susceptible to variations in thickness of cover-glass as dry lenses, the oil film having the effect of making the front of the objective and the cover-glass a continuous whole. It is, however, important that they be used with the tube-length for which they are corrected.

Colour Filters.—In all objectives other than those of the Apochromatic series, there is of necessity a residual colour in the corrections.

The working of a good objective can be made equal to that of the Apochromatics by the use of a colour

filter. If this filter has a definite range of wave-length only the one colour can pass, all others being absorbed and the best result is in consequence obtained.

Coloured glasses and light filters have, however, another province of usefulness. They are invariably used for Photo-Micrography to produce contrast effects in coloured objects, but it does not seem to be understood that they are valuable for visual work.

There are certain colours used for double-staining, and other bacteriological work, which do not stand out with sufficient strength by themselves, and the resulting image depends on the relation of the outstanding colour in the objective to the staining of the object.

For this reason **we always supply a disc of yellow glass with our** 1/12th″ **Oil Immersion Objectives,** to strengthen the contrast in bacteriological specimens, and a disc of blue glass for routine work with the lower power objectives.

General Hints.

Medium and high-power objectives should never be taken apart, because they are centred in the position in which they are screwed when sent out. If by any chance they should become dirty, they should be returned to the makers. Care should be taken to keep the front lens clean, the best material to wipe it with being an old silk handkerchief or a piece of linen **that has been washed many times.**

All lenses requiring internal cleaning should be returned to us. **Under no circumstances should lens components ever be separated,** as it is impossible without special machinery to recentre the optical combination.

It occasionally happens that a lens is returned to us with the remark that it has suddenly ceased to perform well, and on examination it is found that a very fine film of Canada balsam or other material used for mounting objects has covered the front lens. Being of a transparent nature it is not quickly detected. We suggest that this should be looked for with a pocket-lens, if a sudden lack of definition arises.

It will be found best always to commence the examination of an object with a low power, subsequently using a higher one, as may be found necessary. A much better idea of the whole object is obtained in this way.

EYEPIECES.

It has been previously stated under the heading of objectives that the initial powers of an objective and an eyepiece multiplied together give the magnifying power that is being used. Every eyepiece sent out by us bears a figure denoting its magnifying power, so that ready calculations may be made. Correction must be made for variations, if any, in tube length. See note under magnification table.

The Field.

Considerable misconception exists regarding the diameter of field that is seen. The extent of the object that will be embraced and seen at one time is naturally greater with a low than with a high magnification, but we are referring now to the diameter of the circle or field that is seen when looking through the instrument. This is controlled largely by the diaphragm in the eyepiece—if this has a large opening the diameter of the circle is increased, if small, it is diminished. The diaphragms are all made to give the circle or field that is most advantageous and convenient, and although a large field may be at times useful for low-power work when following the movements of living objects, etc., it is distinctly disadvantageous with objectives of medium and high magnification, because only one part of the object is seen sharply at one time—see note *re* Flatness of Field, page 16.

THE MICROSCOPE STAND.

Its Preservation.

To secure permanent and accurate working the microscope must be treated with consideration and care. Watson Microscopes will retain their working qualities indefinitely despite wear, owing to the provision for adjustment by means of compensated bearings, which is included in the design.

Under our guarantee we offer to make any desired adjustments free of charge at any time within two years of the purchase of the microscope. It is, however, impossible for all workers—especially those resident abroad—to have their instruments adjusted by us or

THE MECHANICAL STAGE.

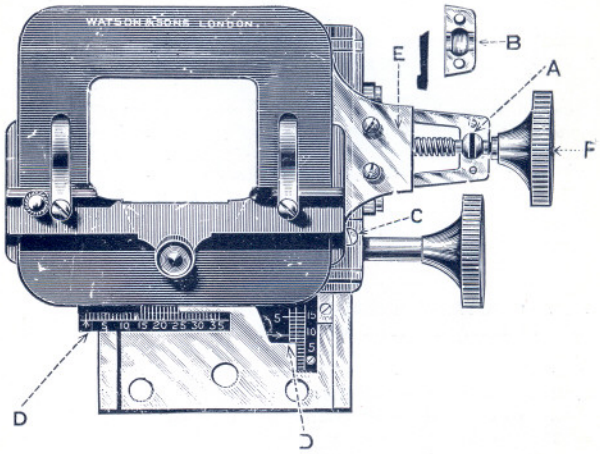


Fig. 5.

Surface View of Mechanical Stage of "H" Edinburgh Student's, "Royal" and "Van Heurck" Microscopes.

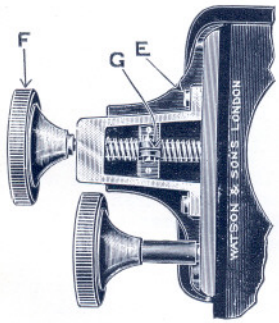


Fig. 6.

View of Stage from under-side, showing attachment for screws controlling horizontal movement.

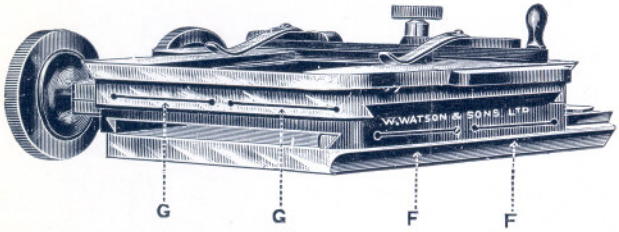


Fig. 7.

View of Mechanical Stage, to show method of springing and use of screws for taking up wear and tear.

even by a skilful mechanician; they have, therefore, been so designed as to enable the user to make his own adjustments.

Instruments in which machinery plays the predominant part in manufacture, such as the "Service," have different means of adjustment, the principle is the same as in the hand-made instruments, but the method is slightly different. If, however, the following hints be read, the means for taking up slackness in the "Service," "Bactil" and "Patna" model will be easily perceived. Fig. 1, page 3.

The coarse adjustment slides are machined from a heavy brass casting, which is slotted throughout its length. On the farther surface of this slot is mounted a steel plate, and the screws No. 30 impinge on this plate. If after a period of prolonged use wear takes place it is only necessary to slightly tighten two of the screws provided to compensate in the area over which wear has taken place, the dovetail bearing will then be expanded to form an accurate fit with the female slide. Under no circumstances should the pinion be touched, this only has the effect of increasing the friction on the pinion.

Compensation for the fine adjustment is on the reverse principle, the three screws No. 5 provided have the effect of drawing the opposed slides towards each other.

It is possible to readjust the slide on one of these models of microscope within a very few minutes, even after many years' use. It will be found advisable before carrying out these adjustments to remove the body from the slide and to thoroughly wipe the bearings, re-lubricating them with a little clock-maker's oil.

For hand-made microscopes, such as the "Van Heurck" series the method is as follows :—

On pages 23 and 24 views will be seen of our Standard Mechanical Stage.

The manner in which the movements are fitted will be plainly seen, and the method of fitting and taking up wear and tear is as follows :—

The stage surface is seen full in view in Fig. 5, page 23. The horizontal travel of the stage is controlled by the rotation of the milled head F, which, however, remains stationary—that is, it does not travel with the traversing plates of the stage. The plate E is connected with the long screw operated by the milled head F, and the screw is supported by a slotted collar G, which gives adjustment for wear, as shown in Fig. 6. To secure the smoothest possible motion, the screw has a ball fitting, as shown at A, Fig. 5. The little plate B fits over the ball and is so attached that no internal shake takes place. C is the adjusting screw for regulating the pressure of the pinion upon the rack in the vertical movement of the stage.

The bearings or dovetails of the stage have slots through which screws pass at FF and GG, as seen in Fig. 7, which is a corner view of the stage, and any wear that may occur in the plates can be immediately taken up, the same method being adopted for so doing as previously described in connection with other fittings and later. The coarse and fine adjustments have similar bearing slots, No. 28, page 6, and adjustments are made by the screws numbered 5.

To Clean the Coarse Adjustments.

Rack the body and its fittings upwards completely out of their bearings. The bearings and the fittings attached to the body should then be thoroughly cleaned with paraffin oil and a clean rag, and subsequently wiped quite dry. Two or three drops of best watchmaker's

oil, which contains no acid, should then be placed on the bearings, and the body once more racked in. Adjustment should then be made by means of the body screws, which will be seen when the microscope body is racked upwards until, with the microscope in a vertical position, the body will move slowly through the fittings by gravity (to check this it is permissible to remove the rack to avoid interference by the pinion), and at the same time no shake is felt in the bearings. If there should be shake in any position it can be at once controlled by means of the screws No. 30.

To Clean the Fine Adjustment.

Remove the two screws from the plate No. 29, but, as this plate covers a spring which produces a reactionary effect in the fine adjustment, it must be held in position very firmly until the screws are actually removed, and then care must be exercised lest the spring should shoot the plate some distance. When the screws are removed the pressure on it should be gradually released so that the tension of the spring is spent. The spring should then be removed, and the body with the fine adjustment slide can be slid upwards. These should be treated in precisely the same way as the coarse adjustment, and so adjusted that the outer fittings slide over the inner by gravity, when the instrument is in a vertical position, with an entire absence of shake. The final adjustments, if shake be present, are to be effected by means of the screws No. 5.

The same process can be repeated with regard to the stage and its fittings, and provision of a similar nature is made in the substage. In fact, all working parts are provided with their compensating screws and slotted fittings, by means of which wear and tear can be taken up.

These special fittings, which are a great feature in the Watson microscopes, necessitate extreme care and accuracy in manufacture, and, in consequence of the appreciation of their successful working some other makes of microscopes have been provided with so-called compensating screws, which are, in fact, dummies, for no spring fittings are provided by means of which compensation can be effected. We venture, therefore, to mention this fact. All our instruments, even the very cheapest, are provided with the compensating screws and slots.

Note most particularly we do not consider it desirable or necessary that any user of the microscope who is able to let us have the instrument should take it to pieces and clean it himself. It is to our interest to ensure for the worker the utmost comfort and accuracy in his instrument, and it is a pleasure to us to keep microscopes of our own manufacture in the best possible condition.

Fig. 8.
Scales and Verniers.

SCALES AND VERNIERS.

The method of reading the vernier is this : First, the zero line of the vernier is used like an ordinary index to find the whole number of millimetres of the scale ; in the figure the zero line points between 12 and 13 of the main scale, hence the whole number is 12. To find the fractional part to be added to this, the other lines of the vernier must be examined in order to find that which most nearly falls into exact alignment with a line of the main scale. This having been done, the corresponding number of tenths of a millimetre is obtained by the aid of the figures engraved on the **vernier :** the first of these being 0, the last 10, one sees at a glance that if all the lines of the vernier were numbered, the one at which coincidence takes place in Fig. 8 would bear the number 7 ; hence the complete reading of the vernier in this figure is 12·7 mm.

A little practice will soon enable this to be done with facility.

Cleanliness.

It is very important that a microscope should be kept in clean condition. Where it is constantly exposed in the laboratory, a ready means of protection is to be found in a bell glass cover, which can be put over it quickly when not in actual use. The instrument should be carefully wiped before use on every occasion.

Never oil the bearings of the microscope unless quite sure that the oil is perfectly pure and free from acid. Watchmaker's oil is the best.

Never use the immersion oil for lubricating the fittings of a microscope. It is really of a resinous nature and works havoc with the fittings.

Above all things, it is desirable that those who use the microscope should be cleanly. Lacquer is soluble in spirit. Fingers which have been dipped in spirituous media should not be brought in contact with the microscope while in a moist condition, otherwise its appearance will be spoilt. Care should be taken not to touch it with hands covered with media and reagents.

Dust.

It is exceedingly difficult to remove from the field certain slight specks which can be seen when looked for. Whenever any specks appear they can at once be located by ascertaining which portion they are in. If, on rotating the eyepiece, they move, the trouble is there; if moving the object causes them to traverse the field, the object is accountable for them. If neither of these shows the position, they must be looked for in reflections from the lamp-glass, or finally the objective. These specks are not usually very obtrusive, but are observed when the attention is not so much concentrated on the object as on a critical survey for such imperfections.

An eyepiece should always be left in the draw-tube to prevent an accumulation of dust on the sides of the tube, which will, in turn, fall on to the back lens of the objectives.

Working should always be done with the eye close to the eye-lens of the eyepiece. If the head is held some little distance above, many fancied defects may appear.

Acquire the habit of working with either eye and keeping open the eye which is not actually employed in observation Those who find difficulty in doing this should use an eyeshade.

To clean the eyepiece lenses, a soft clean cloth dipped in spirit will remove the dust. The lenses must be carefully wiped dry after such treatment.

When using an Oil Immersion Condenser or "Holos" Immersion Paraboloid, the use of golden syrup—the ordinary domestic syrup—has been recommended instead of oil. With this, contact is maintained more continuously. It must not be used for objectives.

HOW TO MEASURE MICROSCOPIC OBJECTS WITH THE EYEPIECE MICROMETER AND STAGE MICROMETER.

The stage micrometer is placed on the stage, and the eyepiece micrometer is put into the eyepiece. This latter is generally divided into parts of a centimetre, but no exact value is needful so long as the lines are equidistant. On focussing the stage micrometer the two sets of lines will appear in the field at once. It is now desirable to ascertain how many divisions of the eyepiece micrometer are included between one of the spaces, that is, 1/100th of a millimetre of the stage micrometer. Perhaps it will be found that there will be several lines of the eyepiece micrometer and a fraction in that space, and in order that this fraction may be obviated the draw-tube should be slightly pulled out; this will increase the magnification until a definite number of the lines on the eyepiece micrometer are exactly equal to a division or divisions on the stage micrometer. We will imagine that the number of eyepiece micrometer lines that fill 1/100th of a millimetre of the stage micrometer is 5. The stage micrometer is now removed and the object to be measured replaces it. The lines of the eyepiece micrometer will be seen in the field, and bearing in mind that five of these lines equal 1/100th of a millimetre, any part of the object can at once be measured.

It must be remembered, however, that with every objective and at every tube length an estimation of the value of the eyepiece micrometer is necessary.

LARGE LENSES AND HIGH MAGNIFICATION.

To those who will put the matter on paper thoughtfully, it will immediately become apparent that a combination of large lenses and high magnification is impossible.

It is generally known that magnifying power depends on the focus of the lens, and that the focus of the lens depends on its radius.

Bearing in mind that the focus is twice the radius (approximately), it will be seen that a lens with its maximum curvature, viz., a hemisphere, could only have a focus equal to its diameter.

Suppose now we assume that the lens is 1″ in diameter, and has the maximum radius of 1″, the utmost magnification that could be obtained with it would be 10 diameters. Increased magnification would of necessity mean a smaller size of lens, because magnifying power depends on focus, a lens 1″ diameter having a nominal power of 10, one of ½″ 20 diameters, and so on.

It so frequently happens that a lens of 3 inches, or even 4 inches diameter, of high power is specified. The former could easily magnify about 3⅓ diameters and the latter 2½ diameters, and no more—not very "high" magnification—and the spherical aberration or distortion would make it almost valueless.

Combinations of lenses enable a variation to be made in favour of somewhat larger diameter than is the case with a single lens, but in the main the lines mentioned may be taken as definite, and if high magnification is wanted, it cannot be in conjunction with lenses of large diameter.

The question of spherical aberration, distortion, etc., is left out of the above consideration, but they obviously play a very important part, especially with large lenses.

Generally speaking, a lens should be expected to be not larger in diameter than half its focus. A ½″ lens of 1″ focus, and a 1″ lens of 2″ focus are good working conditions.

If you are at any time in difficulty or doubt about manipulation, or you need suggestions for making your working easier or more effective, or have any optical problems, communicate with W. Watson & Sons, Ltd., who always take a special pleasure in rendering any service in their power to Microscopists in general and to users of their Instruments in particular.

MAGNIFYING POWERS (in nearest whole numbers) of WATSON'S OBJECTIVES AND EYEPIECES.

Image Distance 250 mm. Tube Length 160 mm.

PARACHROMATIC OBJECTIVES.	*Primary Magnification at 160 mm. tube length.*	*Micrometric value.*	*Combined magnifications at 160 mm. tube length with* Huyghenian *eyepieces.*					
			×5	×6	×8	×10	×12	×15
Inch.								
4	0·6	250μ	3	4	5	6	7	9
3	1·25	200μ	6	7	10	12	15	19
2	2·5	58μ	12	15	20	25	30	37
1½	3·5	41μ	17	21	28	35	42	52
1	6	25μ	30	36	48	60	72	90
⅔	9	16·0μ	45	54	72	90	108	135
½	13	11·3μ	65	78	104	130	156	195
¼	26	5·5μ	130	156	208	260	312	390
⅙	42	3·5μ	210	252	336	420	504	630
⅐ (o.i.)	42	3·5μ	210	252	336	420	504	630
⅛	51	2·1μ	255	306	408	510	612	765
1/10	60	2·1μ	300	360	480	600	720	900
1/12 (o.i.)	96	1·5μ	480	576	768	960	1152	1440
1/16 (o.i.)	106	1·3μ	530	636	848	1060	1272	1590

APOCHROMATIC AND HOLOSCOPIC OBJECTIVES.	*Primary Magnification at 160 mm. tube. length.*	*Micrometric value.*	*Combined magnifications at 160 mm. tube length with* Holoscopic *eyepieces and field of view.*			
			×7	×10	×14	×20
mm.						
25	6	24·8μ	42	60	84	120
16	8	18·0μ	56	80	112	160
12	13	11·6μ	91	130	182	260
8	19	7·3μ	133	190	266	380
6	23	6·2μ	161	230	322	460
4	37	3·9μ	259	370	518	740
2 (o.i.)	84	1·7μ	588	840	1174	1680

With a shorter or longer tube the magnification can be ascertained by making the tube length employed the numerator and 160 the denominator, and multiplying the above figures by this fraction. Thus, to ascertain the magnification at 180 m/meters of a ⅙-in. objective and ×6 eyepiece, the following would be the method—$252 \times 180 \div 160 = 284$.

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