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By Prof. J. LAWRENCE SMITH, 1873

INVERTED MICROSCOPE:

A NEW FORM OF MICROSCOPE; WITH DESCRIPTION OF A NEW MICROMETER AND GONIOMETER.

The instrument forming the subject of this article was invented by me in the summer of 1850, and first brought to the notice of the *Société de Biologie* of Paris in the month of September of the same year, and with additional improvements in the micrometer movement was laid before the American Scientific Association in 1851. Besides the mention made of this instrument in the minutes of the proceedings of those scientific bodies, no account of it has been published giving a full detail of the objects sought after and effected by this new form of microscope; and this I now hasten to do, in justice to myself, since seeing in the last edition of Quekett's work on the microscope a short description of this instrument under the title of Nachet's Chemical Microscope. How it is that my name has been entirely omitted in connection with it is a mystery to me; it must have arisen through Mr. Nachet's neglect to mention who the inventor of it was while exhibiting it at the World's Fair in London in 1862, or through the forgetfulness of Mr. Quekett after being informed on the subject. This omission is still more glaring, from the fact that the instrument as then exhibited, with one or two very unimportant modifications, is the same in all its mechanical details as was constructed for me, from my plans, by Mr. Nachet, of Paris, and used in the laboratory of Messrs. Wurtz and Verdiel.

I am sorry to be obliged to preface the description of the microscope with this reclamation; but after considerable experience I feel that the instrument is an important one for general as well as chemical purposes, and that it will in time be considered a decided advancement in the construction of microscopes. With these views in the matter I am unwilling to yield what little credit might be due the inventor of it.

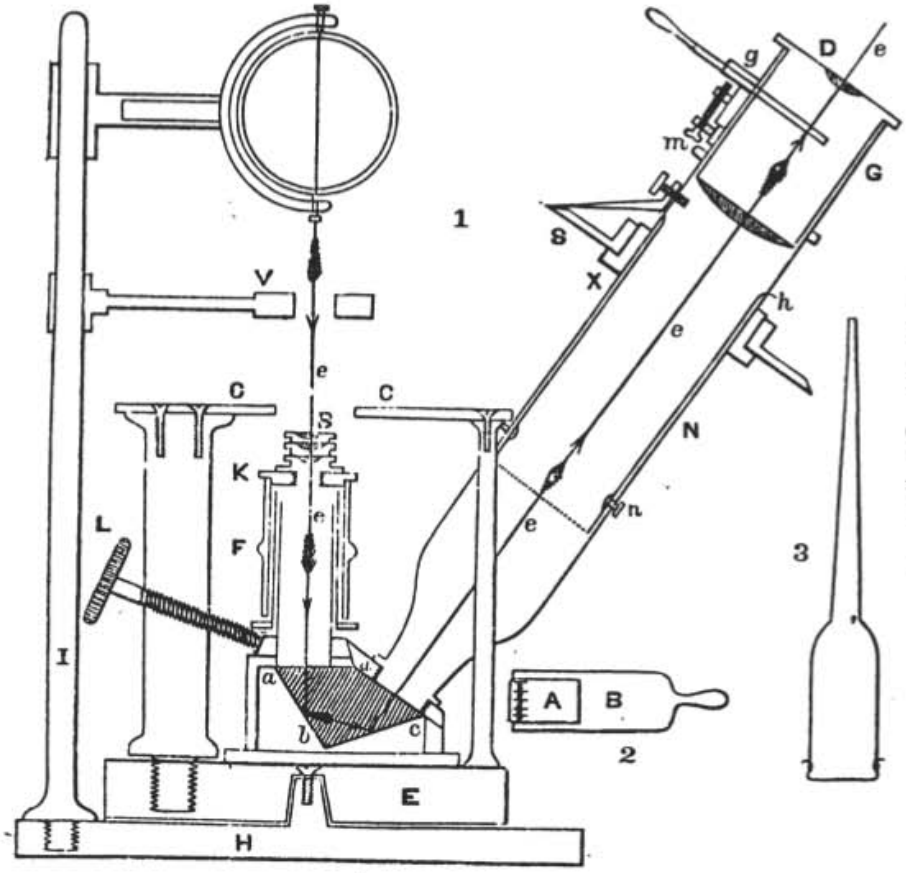
The great development made in microscopic research during the last twenty or thirty years is due in great part to improvements in the construction of achromatic object-glasses; still the mechanical arrangements of the instrument have contributed their share to facilitate observation and diminish the fatigue dependent upon this character of research. In fact, observers have not hesitated to make use of different descriptions of mounting in their varied field of research, and now we have instruments for general purposes, but the construction of which is imperfectly adapted to certain special researches; as, for instance, the dissection of animal tissues. This last circumstance has given rise to the invention of various forms of dissecting microscopes, such as the Pancreatic Microscope of Oberhauser, and more recently the simple and better instrument for arriving at the same end constructed by Nachet, of Paris.

These remarks are made to show how the use of the microscope might be extended by paying proper attention to its mechanical arrangements, and it is from this cause I have been led to seek out a form of instrumant by means of which microchemical research might be facilitated and enlarged. The instrument about to be described is calculated to produce these results.

The great obstacles to chemical research beneath the microscope are twofold: first, the necessity of manipulating in the limited space between the object-glass and the stage; and secondly, the exposure of the most essential parts of the instrument to the vapors emanating from the re-agents employed, and the condensation of vapor on the under-surface of the object-glass, thereby obscuring the view. A less important obstacle is the impossibility of heating a liquid or other substance while beneath the microscope.

The only way by which these difficulties can be surmounted is to place the object-glass beneath the stage and the object above it, with an optical arrangement of such a nature as to permit observation. It was with this view that M. Chevalier made a chemical support to go with his general instrument; but those familiar with it know how awkward it is for manipulation, although exceedingly ingenious, and doubtless as perfect as could be for attaching to his instrument. Feeling then the

want of something more effective, I was led to the construction of the inverted microscope entirely with reference to its chemical uses, other purposes to which it might be applied being of secondary consideration; but I would here remark that since its completion its value even in this latter respect yields to no other form of instrument, and has induced me to change



its original designation of Chemical Microscope to that of Inverted Microscope, as the former name might mislead as to the extent of its uses.

It was important for the arrangement in question so to have the relative position of the stage and eye-piece that the eye, while on a level with the latter, could readily see the former and guide the required manipulations.

Without entering into any detail of the steps taken in the construction of the instrument, I will at once proceed to a

description of it that will be readily understood by referring to the figure. The most important part is a four-sided prism, with the angles *a*, *b*, *c*, *d*, respectively 55°, 107½°, 52½°, 145°, the angles being of such dimensions that a ray of light passing into the prism in the directions shown by the arrows, and perpendicular to the surface *a d*, after undergoing total reflection from the inner surfaces *a b* and *b c* (on both of which the light strikes at an angle much less than forty-five degrees), will pass out perpendicular to the surface *c d*. If the line *c* be followed, it will be readily seen how a ray of light passing through the object-glass B descends into the prism and passes out of it upward through the eye-glass D, the tube of which is inclined to the perpendicular 35°. The other parts of the instrument are understood by simply looking at the figure. E is a heavy support that revolves on another support H, which carries a column I, on which are placed the mirror, diaphragm, etc. The prism used has each side nearly an inch in length, and little less in width, which is about the most convenient size. The arrangement for adjusting the focal distances is somewhat peculiar, and is readily understood by reference to fig. 4. There are three tubes (the outer one of which is F) that slide on each other; the inner is fastened to the plate O; the second tube has a projecting collar, on the under surface of which rest the extremities of two springs *y*, and on the upper surface two points of the lever X, which is moved by means of the screw T. The plate O is fastened on to the top of the prism by the binding-screw L (fig. 1), that readily allows of the plate being detached at pleasure, which it is necessary to do at times in order to wipe the upper surface of the prism. The way in which the observer operates is to screw one or other of the object-glasses to a small cap, K (fig. 4), that simply rests on the upper end of the outer tube F, which is readily moved up and down by the finger for the coarser adjustment, while the minute adjustment is obtained by moving the screw T.

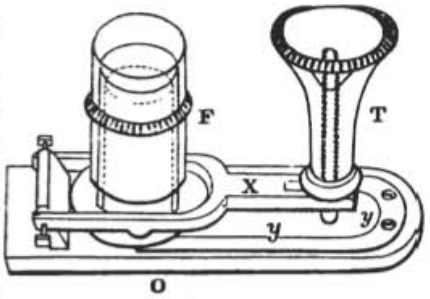


Fig. 4.

This description suffices to make it clearly understood how

the instrument is used, and the conveniences arising therefrom. In examining an object with this microscope the object is arranged in the ordinary way; when liquid it is placed in a watch-glass, or such glass cells as are convenient to use. In employing re-agents they can be added and their effects watched immediately, for it is readily seen how the eye guides the manipulations on the stage, and looks into the instrument almost at one and the same time — a circumstance that facilitates and renders highly satisfactory all such operations, as nearly two years' experience has convinced me.

With this arrangement we need not hesitate to employ hydrofluoric acid among our re-agents, as Prof. Bailey has already done, for the purpose of settling, in a most ingenious manner, that the markings on certain microscopic siliceous animalculæ are elevations, and not depressions, as they disappear last under the action of this acid.

Under the supporting ring V are placed the diaphragms, palarascope, achromatic condenser, etc. I have also arranged a small ring of ivory, through the edge of which two wires pass, that can be made the poles of a galvanic battery, and thereby subject any thing to an electric action while on the microscope. The extremities of the wires may be united with a spiral of small platinum wire, which would become heated by the passage of the electricity, and in this state can be brought immediately over the object under examination.

There is another and very simple method which I have adopted for heating or evaporating liquids while on the stage of the microscope. It consists of a thin plate of brass, about five inches long and an inch wide, with a hole in the center. About an inch and a half each side of the hole there are two screws projecting about the tenth of an inch. When required it is placed on the stage with the projecting screws downward, that prevent the plate from touching the stage, and the part of the plate projecting beyond the stage is heated by a small lamp. The heat is readily propagated along the plate, and imparted to the glass that may be placed along it.

In using this instrument for chemical purposes it is very necessary to be able to apply the re-agents conveniently, and for this purpose I place such of them as are used in two ounce vials, in the neck of which there is a small drop tube, as repre-

sented in fig. 3, over the top of which is stretched a piece of sheet india-rubber, and by pressing and relaxing it the liquid is drawn in, and by pressing the same the smallest possible quantity can be discharged on the object subject to examination. The tube also serves as a stopper to the vial, for the length of the capillary extremity is such that it reaches nearly to the bottom.

The acids and ammonia used are always diluted to about one half their ordinary strength, to prevent any unnecessary disengagement of vapors.

A movable stage, under many circumstances, is very convenient, and I have adopted one of a very simple character, and quite equal to any of those where the motion is produced by screws or pinions. It is a circular plate of metal or glass, about three fourths of an inch less in diameter than the fixed stage of the instrument, and an eighth of an inch thick, with a hole in the center of nearly an inch diameter. This is laid in the stage of the instrument, the glass sustaining the object placed on it, and when required the former is moved by the fingers, which can readily impart to it the most delicate motion, as they are in part supported by the edge of the fixed stage. For this suggestion I am indebted to Prof. Riddell, and both he and myself, after much experience, feel convinced of its usefulness.

In observing with high powers, as the object-glass is beneath the glass supporting the object, and as this glass is usually of a certain thickness, we have to change our method of observation—for all powers resorted to in chemical examination this difficulty never occurs, and in using high powers it is easily obviated. Where the object is already mounted and dry, the thin glass can be readily turned downward; but where it is moist—as, for instance, in examining fresh *Desmidiæ* and *Diatomaciæ*—the following plan is resorted to, namely, to use a cell made of a thin piece of brass or glass, perforated with a hole about half an inch in diameter; it is best to give the hole a considerable bevel in one direction, as it facilitates the cleaning of it; over the small end of the hole a piece of thin glass is stuck with balsam or other cement. When used the object to be examined is placed within, and a cover of thin glass placed above. When brass is used to make the cell it may be as thin

as the twentieth of an inch; and I have two such in my possession, made for me by Prof. Riddell, and they are certainly the most convenient things of the kind I have ever used. And here I may remark that for all observation with high powers the Inverted Microscope is decidedly superior to the ordinary forms of mounting; for in the latter case, when an object-glass of a one-twelfth or one-sixteenth inch focus is used, the focus is too short to admit of the use of cells; whereas in the inverted form, as the object is looked at from beneath, the cell may be as thick as one pleases. Another thing that I have discovered connected with this class of observations is that the *Desmidiæ* and *Diatomaciæ* can be observed to much greater advantage from beneath than from above, for reasons that will be obvious to persons accustomed to observe these classes of objects.

Another advantage possessed by this instrument, calculated to extend its use for general purposes, is its great capacity for every variety of illumination, without sacrificing the ease and freedom from fatigue belonging to the use of this form of microscope; for when placed on a table, rather higher than the one commonly used, and a foot or two from the edge, the observer can recline on his arms, and observe for hours without the slightest sensation of fatigue.*

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* As Prof. Riddell, of the Medical Department of the University of Louisiana, has been using my microscope for general purposes for more than a year, I requested of him his opinion as to its advantuges, which is expressed in the following letter:

Prof. J. LAWRENCE SMITH: *Dear Sir.*—In reply to your note respecting your Inverted Microscope, I have to say that having formerly been in the habit of using the mountings of Pritchard, Dollard, Raspail, Chevalier, and Nachet, and having the past year constantly used my best lenses (Spencer's make) in the inverted microscope, I am fully satisfied of the practical superiority of the latter for general purposes. With it observation can be made with more ease and comfort, the light admits of more convenient and efficient management, chemical re-agents can be applied to the object with the greatest facility, without endangering the instrument, and the slides can be moved or changed with the utmost facility, and with perfect safety to the object-glass and the slides themselves. The instrument is so firm as to manifest no vibration with the highest powers, and admits of the attachment of every collateral appliance. I shall never willingly return to the habitual use of any other known form of microscope, especially with high powers. The excellence of your form of microscope depends on having a good reflecting prism below the object-glass. The one used by me, made by Oberhauser of Paris, seems to be perfection itself, and seems neither to absorb or distort the luminous rays in the slightest degree.

Respectfully yours, J. L. RIDDELL.

Many little additional conveniences will suggest themselves to almost all microscopists who may use this instrument; but the great principle belonging to it is what I desire to make public, and any other adjuncts that may be described are such as belong to all forms of microscopes.

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