

*Human red blood-corpuscles.* Magnified 1000 diameters, by Powell and Lealand's immersion  $\frac{1}{16}$ . Negative 145 (new series).

*Section of an epithelial cancer of the larynx.* Magnified 400 diameters, by Wales'  $\frac{1}{8}$ th. Negative 162 (new series). This Negative is taken from preparation No. 2277, Microscopical Section. The print shows the nuclei and cells of the growth with great distinctness.

*Grammatophora marina.* Magnified 2500 diameters, by Powell and Lealand's immersion  $\frac{1}{16}$ . Negative 151 (new series).

ARMY MEDICAL MUSEUM, MICROSCOPICAL SECTION,  
January 4, 1870.

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The following note Dr. Woodward has requested us to append :—

WAR DEPARTMENT, SURGEON-GENERAL'S OFFICE,  
WASHINGTON, D.C., March 28, 1870.

*Note.*—Since the foregoing essay was printed, I have obtained a number of excellent pictures, with powers ranging from 400 to 1000 diameters, by using the ordinary oxy-calcium light as the source of illumination. Some of these pictures were not inferior to the best work I have done with the Magnesium lamp; the process employed was the same, and the times of exposure did not materially differ. I will contribute full details in a short time.

J. J. WOODWARD.

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#### V.—Remarks on High-power Definition.

By F. H. WENHAM, Vice-President, R.M.S.

I AM induced to offer some observations under this head, in consequence of the communications of Dr. Pigott. I had not the pleasure of being present at the reading of the paper before the Royal Microscopical Society, on 10th November, 1869, or I should have made my comments at the time. Considering the large class of observers that employ their microscopes chiefly for the purpose of resolving difficult test-objects, and the form of their structure, it is surprising that the alleged "bead structure" of the *Podura* and other tests has excited so little discussion; and from the partial acquiescence conceded by our respected President, I infer that this structure finds credence amongst a number who interest themselves in such investigations. Not having now the advantage of being able to attend the meetings of the Society, I will take the question

as I find it recorded in the Journal, in a fair spirit of controversy, being willing either to receive or give any information that may tend to elucidate the truth.

In the first place, I must take some exception to the slur that is cast upon the object-glasses of our best makers, by the assertion that "in the best glasses there is a certain residuary aberration, which obscures the clear definition under a power of 1000." If such an error does not exist, of course all mathematical calculations for demonstrating its character and amount must be in vain.

The high-power objectives, from  $\frac{1}{4}$ th upwards, constructed by our first-class makers during the last fifteen years, may now be named as hundreds. Surely some of these are absolutely perfect, if not the majority; and if any error should be present, the development of a peculiar structure in a test-object is not a certain way of detecting it. In this inquiry, it is remarkable how the use of the mercury globule is ignored; yet I have no hesitation in saying that without this test it would be impossible to construct perfect objectives. To the practised eye of the microscope optician, it will develop errors that can be detected by no other means. With a good  $\frac{1}{4}$ th, for example, under perfect adjustment the spherule appears clear and bright, with the reflexion of surrounding objects shown thereon; and the only fault is that arising from the secondary spectrum, seen as a pale-green halo beyond the focus. It would be desirable to correct or diminish this, but the cure lies more in the hands of the glass maker than the optician. When the globule is thus perfectly defined, if the least possible touch be given to the adjusting collar, altering the distance between the lenses by something less than  $\frac{1}{10000}$ th of an inch, a kind of fog mars its brilliancy, and is the result of spherical aberration, positive or negative, accordingly as the front lens is either separated or brought nearer. Objects seen by transmitted light are most uncertain tests for these errors of aberration.

If an object-glass is adjusted by a *Diatom*, or *Podura*, viewed by transmitted light, and this same object then illuminated on a dark field, it will generally be found that the first adjustment was imperfect, as a fog now oftentimes obscures the object, which is dispelled by further and more careful adjustment, with the more sensitive test of opaque illumination. Thus in the best objectives we have the power of obtaining equally both positive and negative aberration, and the position between them is free from either—supposing that there are no errors of workmanship. These being under the control of the artist do not frequently occur, and cannot be classed as a constant error.

Object-glasses were made eighteen or twenty years ago with smaller apertures, giving as perfect definition as now. Andrew Ross discovered the adjustment for the thickness of glass-cover

over the object, and demonstrated the nature of the aberration caused thereby. We have here, in the separation or approximation of the lenses of a microscope object-glass, an element of correction which cannot be obtained in the telescope, and which, in constructing the combination, enables us to neutralize the spherical aberrations completely, and, to a great extent, without altering the radii. Objectives, from the hands of careful and experienced makers, have all been constructed on the globule test, and are not sent forth till every error of workmanship, centering, state of oblique pencils, achromatism, and spherical aberration—are absolutely corrected; for this test discovers the least fault in either, where all others will fail.

But in viewing difficult test-objects with the highest powers, one source of error may occur from the following cause:—If a large angular pencil of rays converging to a focus is transmitted through a parallel plate of glass, an approximation to the form of spherical aberration is produced of a negative character, *viz.* the marginal rays are thrown beyond the central ones. It may easily be demonstrated that this is not exactly identical in form and character with the positive aberration caused by a lens with a spherical surface, and that the operation of bringing the lenses of the microscope object-glass nearer together for the counter-correction, will only neutralize the error within certain limits. The irregular position assigned to the marginal rays by a very thick plate of glass, cannot be exactly reformed by the opposite error caused by closing the lenses; and it is a well-known fact to those experienced in the resolution of test-objects, that some of the same specimens are defined better under one thickness of covering-glass than another.

In the front lens of an object-glass, *thickness* is a very important element of correction. I have explained this in my paper “On the Construction of Object-glasses;”<sup>\*</sup> and in working out a new combination it may be necessary to make several fronts in order to arrive at the exact gauge. If an ordinary “dry” object-glass, perfectly corrected, with a *proper* thickness of the front lens, be used as a so-termed “immersion” lens by the introduction of water between the front lens and covering-glass, this immediately becomes a part thereof, and the excess of negative aberration, both spherical and *chromatic*, is not to be corrected by the usual separation of the lenses. The whole combination has become over-corrected. Rays, which before the introduction of water emerged from the upper surface of the plate in a line parallel to their first incident direction, now pass on in a nearly straight course from their primary refraction from the under-surface of the cover. In order, therefore, to employ an objective as an immersion lens, it becomes requisite to have a *thinner front*, all other radii and corrections remaining the same. The extra or immersion lens should have its thickness diminished by

<sup>\*</sup> Published consecutively in the early numbers of this Journal.

rather less than the thickest covering over the objects that it is to be employed upon.

We have here, in the immersion lens, gone back to the original condition of again adding thickness to the front, and the object may now be considered under view as an uncovered object. Not either the *water* or glass-cover has introduced a single new element of correction, and will not therefore bear out the following assertion in the paper referred to:—"The extraordinary difference between the performance of the hydro-objective and of the pneumo-objective (the plate of air and water making enormous differences in the aberrations of the glasses) must make it apparent to ordinary common sense that our old-fashioned glasses are wrong somewhere."

One advantage in the immersion objective is, that it almost prevents the loss of light from the reflexion of the upper surface of the cover and front of lens, and in part neutralizes any error of figure or polish that may exist between them. There is also another condition annexed, it has the singular property of a *front lens of adjustable thickness*, and therefore can be set to the utmost nicety to balance the aberrations. Of course there is no optical advantage attendant upon the use of *water*. If a medium of the same refractive power as the glass were to be employed the result would be better. Water having a low refractive index, an adjustment is required for each thickness of cover, and a difference of adjustment is not so marked and sensitive as in the ordinary dry objective; but if a medium of similar refraction to the glass were to be used, no adjustment would be required for any thickness of cover, supposing the test-objects to be mounted thereon (which they generally are), for, in fact, we should then view them all with a front of the same thickness—considering the cover, the front lens, and the interposing medium as one.

Having now given some reasons for repudiating the persistent error assumed to exist in all our best object-glasses, I must of course notice the observations upon which the assurance has been founded. The author of the essay expresses his opinion that this "minute structure of the *Podura* affords the most severe trial for residuary aberration with which he is acquainted." I have three  $\frac{1}{12}$ th object-glasses, and it is most easy to produce the beading with the worst of them. The highest eye-piece should be used, the draw-tube lengthened, and the object placed slightly out of focus. The illumination (with the achromatic condenser) requires long and careful coaxing to obtain the illusion. Figs. 4 to 7 in Dr. Pigott's paper do not fairly represent the appearance. The beads are neither so closely packed or so regular as there shown. The under-beads may appear to cross either to the right or left, according to the illumination or *fancy* of the observer. Having got the beaded form developed to the best advantage, if we now remove the highest eye-piece and

substitute the lowest therefor close in the tube, and adjust the focus (which the change of eye-piece requires), the beaded appearance dissolves into the usual "note of admiration" markings. Another appearance may be very easily obtained in the *Podura*—that of a series of oat-shaped cells, each end terminated by a bright spherule; and with equal reason might be claimed as the real structure. Probably no one has ever examined this object so carefully and systematically as the late Richard Beck. With his own hands he collected hundreds of specimens in many localities and of every variety of species. Some of these he gave to me, and which I value exceedingly. I never once heard him express an opinion that the markings were otherwise than longitudinal ribbings. The surest way of deciding the question is by examining fragmentary pieces of the scale. The insects are not easily obtained at this time of the year, or I would offer some illustrations.

At the conclusion of Dr. Pigott's paper he states that "the surface of metals and alloys, with a power of 1000 diameters, shows under reflected light particles, apparently spherical, agglomerated together, with dark lines separating the particles." The plane surfaces of mercury, well-polished speculum metal, or steel, show no structure, but metals with an imperfect surface are full of glittering points which can be developed as spherules. A broken surface of bright points is by no means a practicable test for the correction of object-glasses, for the numerous images interfere and cause a confusion of the indication which is required from a single point only. When a particle of mercury is beaten into fine dust for the purpose of obtaining a very minute point of light for testing errors, a single atom is isolated, as the comas from surrounding ones would embarrass the result. The broken surface of fine cast-steel consists of angular fragments or crystals; a few of the highest can be seen in focus, those beyond appear as spherules.

At page 192 of this Journal, for April, Dr. Pigott states:—"I had the good fortune to discover yesterday that the median line of the *Formosum* is formed of four parallel rows of beads about one-third the size of the general beading. Every part seems compounded of cohesive spherules." I refer to this as an example of how a false structure may be developed in one part of an object of this character by the interference from adjoining parts. Taking the entire scale of the *Formosum*, this four-banded appearance of beads may readily be shown on the median line, and it would be hard to say that they did not exist; but this *Diatom* is exceedingly brittle, and liable to split down the centre, or close to the median line. I have a slide containing numerous fractured specimens; in one, the midrib stands out quite isolated a distance beyond the broken scale. In this portion, not by any means of illumination, or any object-glass that I can employ, am I able to develop a beading or molecular structure;

there is only a faint indication of a core, or median line. In the portion of this same midrib situated in the scale the rows of beads can be made to appear. I have therefore no doubt that they are spurious. In fact, in the *Formosum* the row of beads next to the midrib are much finer, or about half the size of the others, and a spurious image of these can be thrown within the rib.

Under a  $\frac{1}{25}$ th the *Formosum* is a most superb object. The spherules are perfectly isolated, and appear like beads of coral on a deep sky-blue ground, and at the fractured edge they overhang in some places.

VI.—*On a New Critical Standard Measure of the Perfection of High-power Definition as afforded by Diatoms' and Nobert's Lines.* By DR. ROYSTON-PIGOTT, M.A., Cantab., Fellow of the Cambridge Philosophical and of the Royal Astronomical and Microscopical Societies of London; formerly Fellow of St. Peter's College, Cambridge.

THE study of Diatom- and Nobert's lines unquestionably rewards the ardent observer for years of application and research. By such studies chiefly microscopy has reached its proud position among the advanced sciences of the nineteenth century. What was deemed impossible ten years ago is now with the microscope a common feat performed at will and at once, as the resolution of Rhomboides, which good observers might formerly be hours in attaining.

Further advances can only be made by searching out errors yet to be remedied: it is unphilosophical to declare perfection has been reached—as a bar to inquiry. The satisfied optician, in the face of modern improvements, is apt to feel it would be far better to let well alone and discourage further refinements in optical science. Our motto must still be “Onward.”

The great obstacles to minute observation may be summed up in two words: imperfect correction and exaggerated diffraction.

The former is perhaps insufficiently studied by microscopists, who often purchase their glasses on trust; the latter is a subject which remains to be thoroughly investigated and exhausted. Both these causes distort, derange, and disfigure the true definition of minute objects, and especially the appearance of the celebrated lines of *Nobert's Test-Plate*.

Diffraction lines are not confined to the images of brilliant objects. If a transparent or rather opalescent and pellucid film of a variegated substance traced with dark spots and lines be examined under a high power, when illuminated by the direct rays of the sun,