so valuable a member of the board. As he has all along been one of the most obsequious supporters of the president, having absolutely no will of his own, the grounds of his value are evident. To the credit of the faculty be it said, that most of them refused to be "grafted" for such a purpose. As the institution was founded to promote "religion, morality and knowledge" it is evident from what appears above and from much additional testimony that might be adduced that these terms are just now somewhat "liberally" interpreted.

Chas. W. Super

Athens, O.,
July 22, 1907

SPECIAL ARTICLES

IMPROVEMENTS IN THE ULTRA-VIOLET MICROSCOPE

The resolving power of a microscope varies directly as the numerical aperture of the objective and inversely as the wave-length of the light employed.[1] In other words, the shorter the wave-length the smaller the objects that can be distinguished. Light of half the usual wave-length will show details one half the size of those seen with ordinary light.

The advantage of using light of extremely short wave-length for microscopic purposes has been known for many years and was given clear expression by Czapski in 1891.[2] For some time, however, little or nothing was done to carry out Czapski's suggestions, for several reasons. First, ultra-violet light is invisible to the eye and though able to affect the photographic plate energetically, can not be focused directly even on a fluorescent screen inserted in the camera in place of ground glass, on account of the weakness and indistinctness of the image when high powers are used. Second, the glass of which ordinary objectives are made is opaque to all but the relatively long waves of ultra-violet light which lie just beyond the visible spectrum, which rays give but slightly increased resolution. So little advantage could be gained that glass objectives corrected for ultra-violet light were never made.

Early in the present century, Köhler began experimenting with lenses of quartz and fluorspar, two substances very transparent to ultra-violet light. Such lenses could be used with ultra-violet of very short wave-length which would give greatly increased resolving power.

While Köhler was in the midst of these experiments von Rohr, in 1902, made a great discovery. He invented a new system of lenses made of only a single substance, yet almost perfectly corrected for spherical aberration for light of a certain definite wave-length.

Herschkowitsch shortly before had learned how to make optically homogenous melted quartz in fragments large enough for the minute lenses of a microscopic objective. Under Köhler's energetic leadership, these discoveries were utilized at once and within two years he was able to describe a complete outfit for using ultra-violet rays in photomicrography and to publish numerous plates showing the remarkable performances of this new ultra-violet microscope.[3]

These new lenses, called monochromats, are corrected for ultra-violet light of one definite wave-length—a bright line in the spark spectrum of cadmium whose wave-length is 0.275 μ, or as more commonly written, 275 $\mu\mu$. With ordinary light composed of many wave-lengths, the images given by the monochromatic objectives are distressingly bad, blurred and fringed with rainbow colors due to chromatic aberration, for which the lenses are not at all corrected. It is out of the question to focus the object with such light, and the statement pub-

[1] This is commonly expressed by the formula $d = \lambda/2A$ where d = size of smallest detail resolved by the microscope, λ = the wave-length of the light employed, and A = the numerical aperture of the objective.

[2] Czapski, S., Die voraussichtlichen Grenzen der Leistungsfähigkeit des Mikroskops, in *Zeitschr. f. wiss. Mikroskopie*, 8: 145–155, 1891.

[3] Köhler, Aug., Mikrophotographische Untersuchungen mit ultra-violettem Licht, in *Zeitschr. f. wiss. Mikroskopie*, 21: 129–165, 273–304, Figs. 1–8, Pls. 1–6, 1904.

lished by the Zeiss firm in announcing the new outfit for sale, seemed to be only too true.[4]

The ultra-violet light of the cadmium spark being absolutely invisible (it can not even enter the human eye owing to the opacity of the lens to rays of so short a wave-length), it was necessary to devise some system for focussing the objects preparatory to photographing them. For this purpose, Köhler has used a very ingenious "seeker" which consists of a simple quartz lens and a fluorescent screen placed over the eyepiece. This screen lights up under the action of the ultra-violet rays. If the objects under the microscope be brought to a focus on this screen the image, when the seeker is removed, will be thrown to a focus on the photographic plate some 30 cm. above.

Ordinary glass being perfectly opaque for the rays from the cadmium spark, it is, of course, necessary to make of quartz not only the prisms for separating the rays used for photographing with this microscope, but also the collector and collimator lenses, the substage condenser, the slide and cover, the objective and the eyepiece. Even the ordinary glass substage mirror can not be used but must be replaced by a totally-reflecting quartz prism.

When high power monochromatic objectives are used (and these alone give resolution superior to that of a good visual objective), it is found to be tedious and difficult to get the object in focus owing to the danger of screwing the objective down too far and breaking the cover glass, if not the objective itself. When finally the object is seen, it is found to be impossible to get a sharp focus on the minute details which it is desired to photograph, because of the dimness of the image shown by the seeker. Very minute or very delicate objects, such as bacteria and small protozoa often can not be seen at all, and the observer must focus on an air bubble or some chance particle of dirt in the hope that some of the objects he seeks may lie in the same plane. Such minute, unstained living cells or the equally small constituent organs of larger cells are, however, of most interest for study with the ultra-violet microscope, not only because of the superior resolving power of the new lenses, but also because, owing to the opacity of many parts of the cell to ultra-violet light, the photographs show such living cells as if they had been fixed and stained, giving a welcome proof of the reality of the structures observed in the cells after killing and staining.

While trying to use one of the new microscopes[5] in April, 1906, on such objects, we hit upon a new and in our opinion much better method of focusing.

Instead of employing a single pair of electrode holders as planned by the makers (Fig. 1), we use a double pair of holders (four in all) arranged so that the cadmium electrodes can be instantly swung out and replaced by a pair of magnesium electrodes by means of the handles shown in Fig. 2. The cadmium electrode holders are longer than those for the magnesium for a purpose to be explained later. There is an automatic stop on the lower pair of holders to insure the spark-gap falling in the axis of the collimator lens.

We were led to devise such a swing-out electrode changer by discovering that the monochromatic lenses, through giving only badly blurred and colored images with ordinary light, *did give very good images that could be focused sharply even to the finest detail, providing strictly monochromatic visible light were used.* The spark spectrum of magnesium shows a well isolated line in the blue that proved to be very well adapted for making exploratory observations and for focusing. The wave-length of this line is 448 $\mu\mu$. It is near the line G (431 $\mu\mu$) of the solar spectrum.

In using the ultra-violet microscope by our method the object is first found and centered with a low power visual lens, using the magnesium blue light. Then the high-power

[4] "With light of considerably different wave-length, more particularly daylight, our Monochromats cannot ever be used." Carl Zeiss, Circular M. 170, Jan., 1905, p. 6.

[5] Kindly loaned by Mr. H. G. Kribs, pending the arrival of the highest power objective ordered from Germany.

monochromat is used and a detailed exploration made of the object, using the blue light all the time in a room lighted as much as desired by incandescent lamps or otherwise (the room should be darkened when the photographic exposure is made). Finally, when a particular spot is found of which a photograph is wanted, the camera is moved into place and then all is ready for the exposure except for a correction of the focus of the objective due to the change in wave-length from 448 $\mu\mu$ to 275 $\mu\mu$. This latter correction must be worked out by trial for each objective, but once determined can in future be made in a moment. The objective when used with ultra-violet light must be racked down a considerable distance below the focal point for the blue rays. This distance that the objective must be lowered is read off on the scale of the fine adjustment screw of the microscope stand. In case of our 1.7 mm. monochromatic objective the focal correction amounts to forty divisions of the fine adjustment screw of the Zeiss Photomicrographic stand (about 0.08 mm.).

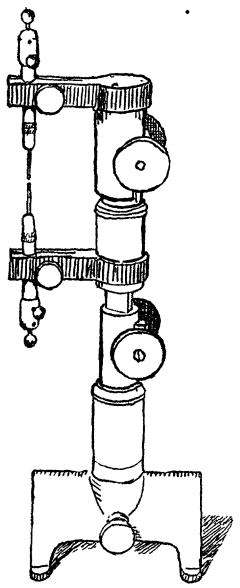

Fig. 1. Electrode holders supplied with the ultra-violet microscope by the maker. Two simple holders with screw clamps to hold the wire (or ribbon) electrodes.

By having the arms of the magnesium electrode holders 5.5 mm. shorter than those for the cadmium it was found possible to bring the blue light and the ultra-violet rays to a focus at the same distance beyond the prisms and collector lens, though not in the same spot, as the ultra-violet rays are refracted much more than the blue rays in passing through the prisms. The illuminating apparatus is made to swing laterally as a whole,

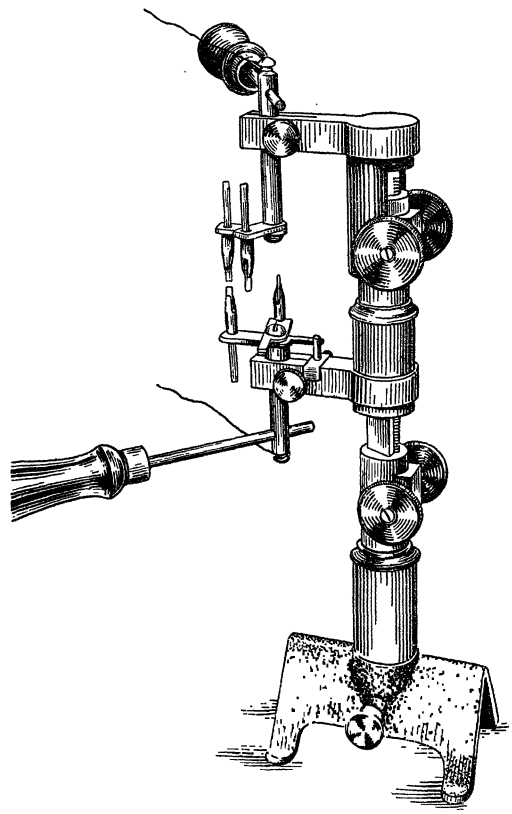

Fig. 2. New swing-out electrode holders. With two pairs of holders; the short ones for magnesium, the long for cadmium. The holders are open above so the electrodes can be removed easily for adjustment. The lower pair have a stop to bring the electrodes automatically in line. Either pair of holders may be thrown into position by turning the handles. About three tenths natural size.

so it is very easy to direct the blue or the cadmium rays upon the face of the totally reflecting prism that throws the light into the substage condenser. By using two stops along the curved way on which it swings the illuminating apparatus can be made to stop automatically at the right place to throw the blue or the ultra-violet light into the microscope.

One great advantage of this system of focusing is that in studying living cells it is possible to do all the exploratory work and to focus exactly on the details to be photographed while using blue light. Only after the adjustments are made is the ultra-violet light thrown on for the few seconds necessary to make the photograph. This prevents injuring the cells with ultra-violet light before they are photographed—an injury to which many delicate cells are very subject, as shown by the investigations of Hertel.[6]

We have made a number of other minor improvements in the ultra-violet microscope, such as a swing-out screen to protect the eye and the microscope from the light of the spark; a pair of insulated rods to hold in place the wires that conduct the high tension electricity from the coil and leyden jars. The strength and the steadiness of the spark have been improved by inserting a few inductance coils in the circuit.

None of the changes are costly and the swing-out electrode holders can be made in a day by any good mechanic for a few dollars. On the other hand, owing to the increased precision in focusing, it will no longer be necessary to buy the whole series of expensive monochromatic lenses. For most biologists, the only one that will be needed is the highest power objective of 1.7 mm. focal length, which alone exceeds the ordinary oil immersion lenses in resolving power.

Finally, it should be noted that the monochromatic blue light of the magnesium spark is very useful for making photographs of microscopic mounts on glass slides with ordinary visual objectives. In fact, no other photomicrographic outfit is so convenient for every day use in a laboratory that is provided with an electric lighting circuit.

The improvements of the ultra-violet microscope here noted were described and exhibited in April, 1907, at the Washington meeting of the National Academy of Sciences and a few days later at the Washington meeting of the American Physical Society. An illustrated account of the ultra-violet microscope and our improvements, together with a few photographs showing its utility in the study of microscopic objects, as well as concise directions for setting up and using the outfit, has been prepared and will shortly be published as a Bulletin of the Bureau of Plant Industry, U. S. Department of Agriculture.

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[6] Hertel, E., Ueber Beeinflussung des Organismus durch Licht, speziell durch die chemisch wirksamen Strahlen, in *Zeitschr. f. allgem. Physiologie*, 4: 1–43, 1904.

CONCERNING THE RELATIONSHIP OF PHYLLOSTICTA SOLITARIA TO THE FRUIT BLOTCH OF APPLES

DURING the past four years, the writer has been collecting specimens of apple leaves and fruits having spots on them caused by fungi. Recently these specimens were examined to determine what fungi are present in the spots. As a result of this examination, it was found that a fungus which caused spots on the leaves and fruits of a wild crab-apple (*Malus coronaria* (L.) Mill.) also caused spots on the petioles and underside of the midribs of the leaves and of the fruits of the common apple (*Malus Malus* (L.) Britton), a condition that might be anticipated.

The spots on the leaves of the crab-apple are either brown or white, about a millimeter in diameter, and with a distinct, raised, brown or purplish border. In the center of the spots there is a single, minute, black pycnidium (rarely more than one). The white spots may be older than the brown ones, both occurring side by side on the leaf. The spots on the