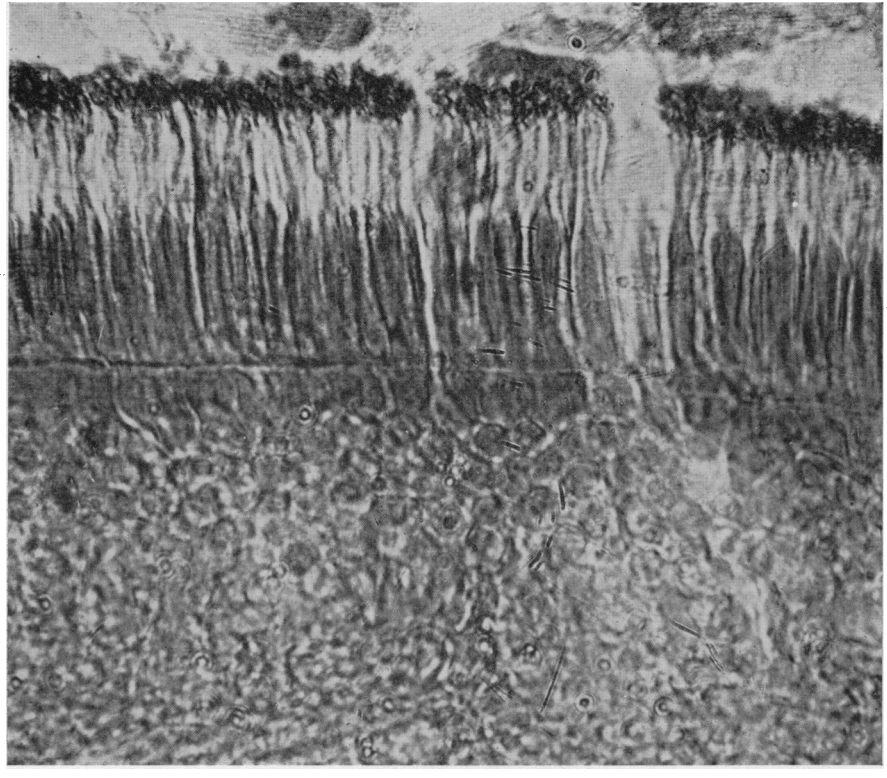


FIG. I. HUMAN RETINA. TERMINAL LOOPS OF CONES IN THE MACULAR REGION.

DR. RISLEY. —These cases were corrected without mydriatic. Perhaps that accounts for it.

DR. THEOBALD. — I think not.

DR. MITTENDORF. — Only the manifest hypermetropia was taken into account. Weak convex lenses absolutely were refused and cylinders accepted and gave perfect vision.

THE TERMINAL LOOPS OF THE CONES AND RODS OF THE HUMAN RETINA, WITH PHOTOMICROGRAPHS.

BY W. F. NORRIS, M.D.

PHILADELPHIA.

In March, 1894, in collaboration with Dr. James Wallace, I published in the University Medical Magazine a paper on this subject. Having since that time, by repeated examinations of retinal tissue, become still more convinced of the correctness of the statements therein made, and having other photomicrographs for demonstration, I desire to call the attention of the society for a few minutes to what seems to me an important advance in our knowledge of the minute anatomy of that complex end organ, the retina.

It is well known that the external segments (members) of the cones and rods are usually described as ending in free extremities or tips which are in close proximity to the pigment layer of the retina, and often covered by and enveloped in it. Some investigators have spoken of them as ending in a swelling or knob.

The photomicrographs, which I herewith exhibit, show that the external extremities of the cones and rods are loops, the outer member of a cone bending over to become continuous with the outer member of an adjacent rod, or less frequently with the outer member of another cone (twin cones). Adjacent rods unite also by their curved outer segments, ending thus also in peripheral loops.

Taking a portion of the retina in the macular region we find the outer segment of each cone becoming cylindrical, apparently

with a woolly surface and with delicate transverse, or, at times, spiral markings. Such a looped outer member in most instances enters the retinal pigment which is often adherent to it for a considerable distance, thus hiding the loop from our view. It is only when we are fortunate enough to find them partially or entirely free from pigment that we can determine their true shape, as they readily break at the loop and thus appear to have blunt or knobbed extremities.

The outer member of a cone, having thus curved on itself, runs down along the side of the inner segment as a cylinder having about the same caliber as at the turn, and after perforating the external limiting membrane passes alongside of the nucleus at the base of the cone, and may be followed for some distance in a tortuous course between the nuclei of the so-called outer nuclear layer, anastomosing, at times, with some of the other nerve fibrils of this layer. In the more peripheral parts of the retina the bacillary layer is still more or less conical in shape, at times nearly cylindrical, the outer extremity bending over to become continuous with the adjacent rod.

In some places, as shown in the osmic acid preparation, we find double or twin cones like those described in the retinæ of fishes, and, in these instances, the bodies of the cones are flattened where they are in contact with each other.

Most of the photomicrographs are from the eye of a boy of twelve years of age, enucleated on the third day after a wound involving the cornea, lens, iris, and ciliary body, caused by a chip of iron which entered the eye and embedded itself in the sclerotic. The wound does not appear to have been infected, as very little inflammation was manifest. The eyeball, after enucleation, was immediately dropped into Müller's fluid, at a temperature of 100° F.

The specimen from which Fig. VI was obtained was from the eye of a child which died of scarlet fever, and was removed about half an hour after death. Notwithstanding the fact that it was in cold weather, lethal changes had probably commenced in the bacillary layer. The rods and cones presented an appearance quite different to that presented by these organs in the eye which had been dropped into the warm Müller's fluid immediately after enucleation. In the former the bodies of the

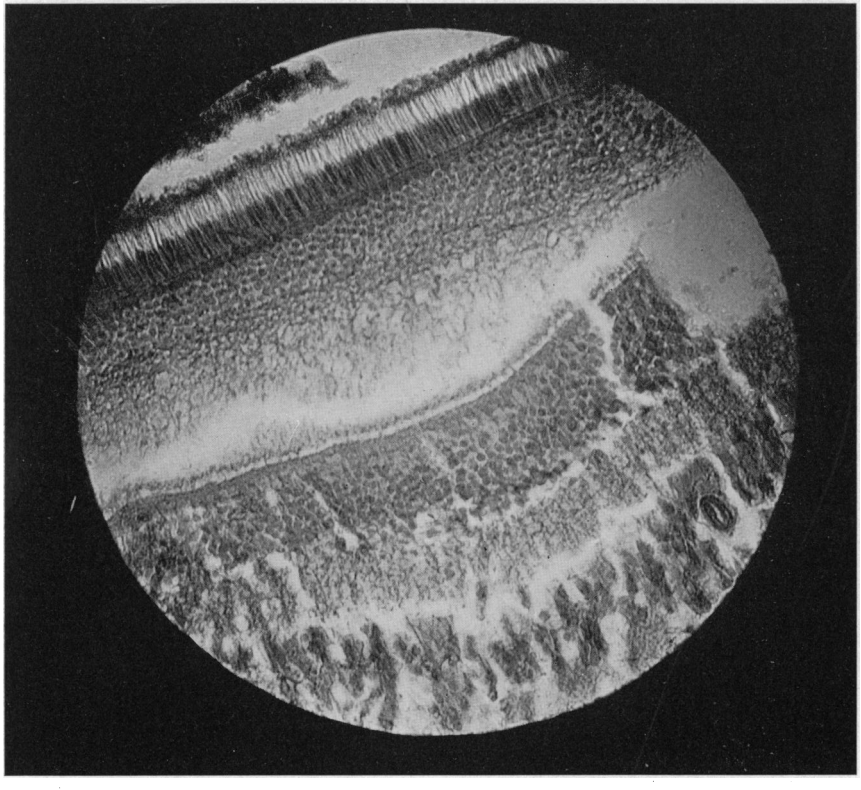


FIG. II. HUMAN RETINA. TERMINAL LOOPS OF CONES IN THE MACULAR REGION.

cones are bulging and thick, with an even surface, making very conical figures, while in the latter they present longitudinal grooves on their surface. Faint longitudinal markings are described by almost all observers, and the exceedingly marked character of these may possibly be due to the shrinking influence of Müller's fluid. Indeed, most of the recent writers on the subject recommend either a 3 per cent. solution of nitric acid or a mixture of osmic acid with bichromate of potassium, either with or without the use of nitrate of silver, as more likely to fix the retinal elements in their true form. I am inclined to think, however, that cones so swollen and turgid as those represented in the osmic acid preparation are undergoing degenerative change, and am confirmed in this opinion by the fact that another perfectly fresh eye, hardened in Flemming's solution (osmic acid and bichromate of potash), gave a picture essentially the same as that found in the specimen hardened in Müller's fluid, and also by a comparison with Pacini's drawings, which were made from an eye obtained twenty-four hours after death and not treated with any hardening agent, the retina having been cut, teased, and mounted for examination in vitreous humor.* Pacini was the first to discover the terminal loops of the cones and rods, but his description appears to have been neglected or rejected as inaccurate. It gives me much pleasure to be able to present to the society for comparison photographs of the drawings in his essay on the intimate structure of the retina.† In Fig. VII, which represents a human retina, we have some swollen cones bending at their outer extremities to form loops and becoming continuous with an adjacent rod; while other rods are depicted as ending in blunt points.

The sections of the human retina, of which I have exhibited photographs, further show that the looped outer extremities of the rods and cones are not all of the same length, but that some reach further out towards the choroid than do others. Almost all writers agree that even allowing for any distortion from the action of the hardening fluid, the cones in the fovea are longer than those in other parts of the retina.

* H. Müller (Gesammelte Schriften, S. 76), in discussing the retina of a pigeon speaks of this degenerative swelling of the cones, and Hannover makes their tendency to swell a characteristic to distinguish them from the rods.

† Sulla Tessitura intima-della retina — memoria di Filippo Pacini — di Pistoja, Bologna, 1845.

Differences in the length of the rods and cones may be seen, however, in many other parts of the retina, even in places where the section is so clearly at right angles to the plane of the retina that there is no room for any mistake, owing to the obliquity of the cut.

The accompanying photomicrographs, six in number, illustrate admirably what I have endeavored to describe in text. They are all from the human retina.

Fig. I is a highly magnified section of a part of the macular region. There are longitudinal folds in the inner members of the cones. The tips of the outer members are more or less hidden by retinal pigment, but in many places are only slightly veiled by it, so as to permit us to see the curve at their outermost part, and to follow the recurrent portion of the loop down along the body of the inner member to its perforation of the limitans externa, and entrance into the outer nuclear layer. Some of these recurrent loops may be seen to anastomose with other nerve fibres in the outer nuclear layer.

Fig. II shows a less magnified view of the macular region, exhibiting distinctly the arrangement described in text to Fig. I. The cones have been but little disturbed by the section; much pigment still adheres to their outer members. In places the loops may be seen projecting beyond the dense pigment which still adheres firmly to the outer member just within the position of the loop. The nucleus at the base of each cone is beautifully distinct.

Fig. III represents a similar portion of the retina less magnified than Fig. I, but more magnified than Fig. II. The loops, in places, show distinctly.

Fig. IV shows the looped extremities of the cones at a point where the preparation has been accidentally broken by pressure of the immersion lens on the cover glass.

Fig. V exhibits a more peripheral portion of the retina, showing the looped extremities of the rods. In both the outer and inner nuclear layers bipolar cells can be seen, and in the fibre layer both multipolar and bipolar cells.

Fig. VI, osmic acid preparation, showing swollen inner members of the cones, well-marked loops of their outer members, and near the center of the plate is seen a twin cone.

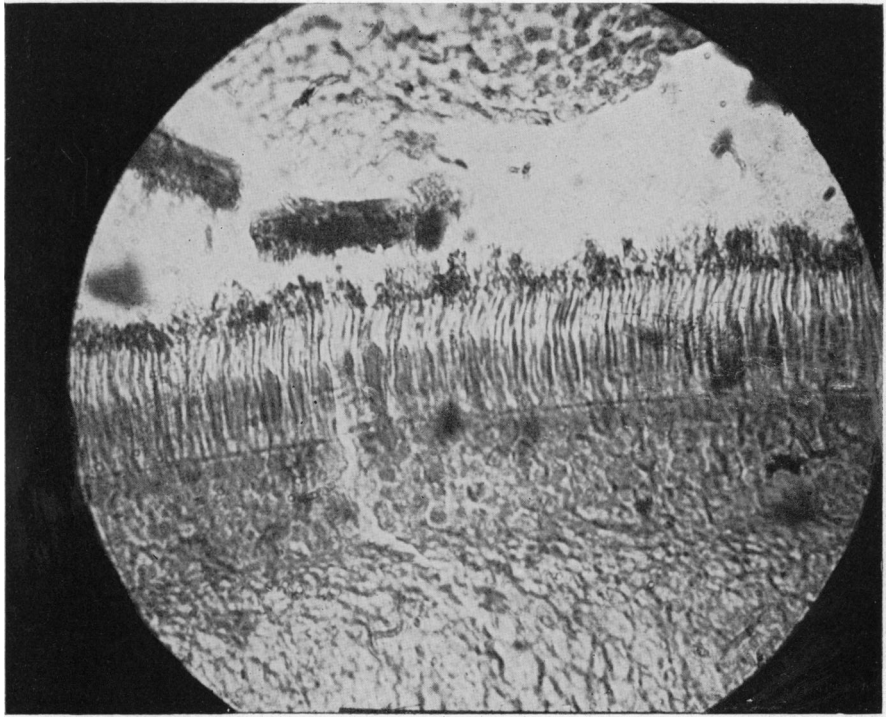


FIG. III. HUMAN RETINA. TERMINAL LOOPS OF CONES IN THE MACULAR REGION.

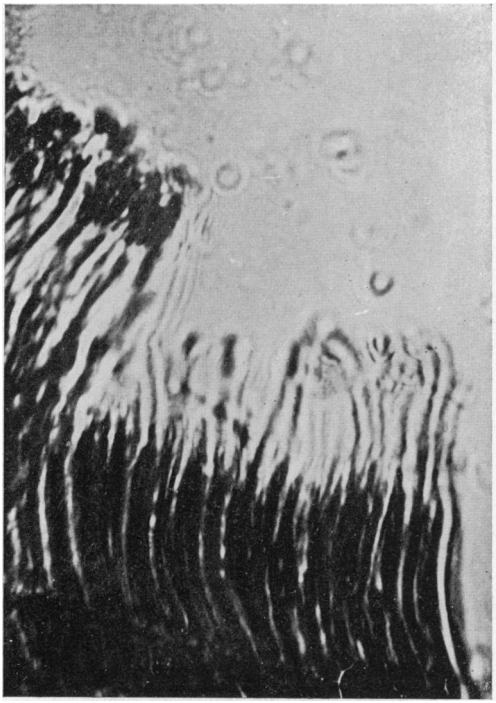


FIG. IV. HUMAN RETINA. TERMINAL LOOPS OF CONES IN THE MACULAR REGION PREPARATION BROKEN BY PRESSURE OF IMMERSION LENS ON COVER GLASS.

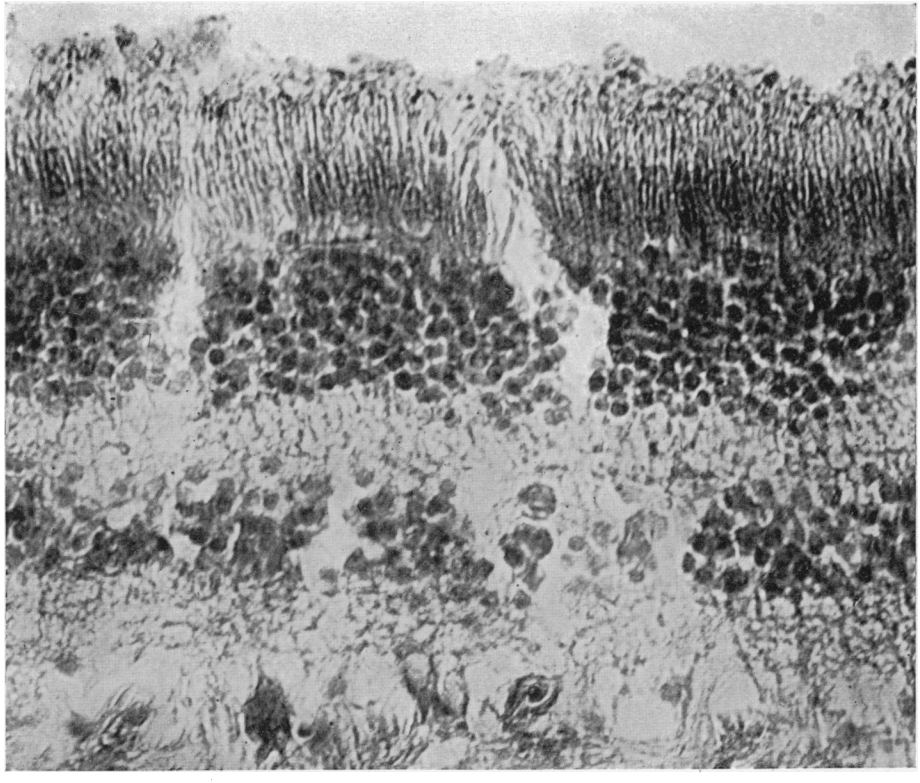


FIG. V. HUMAN RETINA. PERIPHERAL PORTION. TERMINAL LOOPS OF RODS.

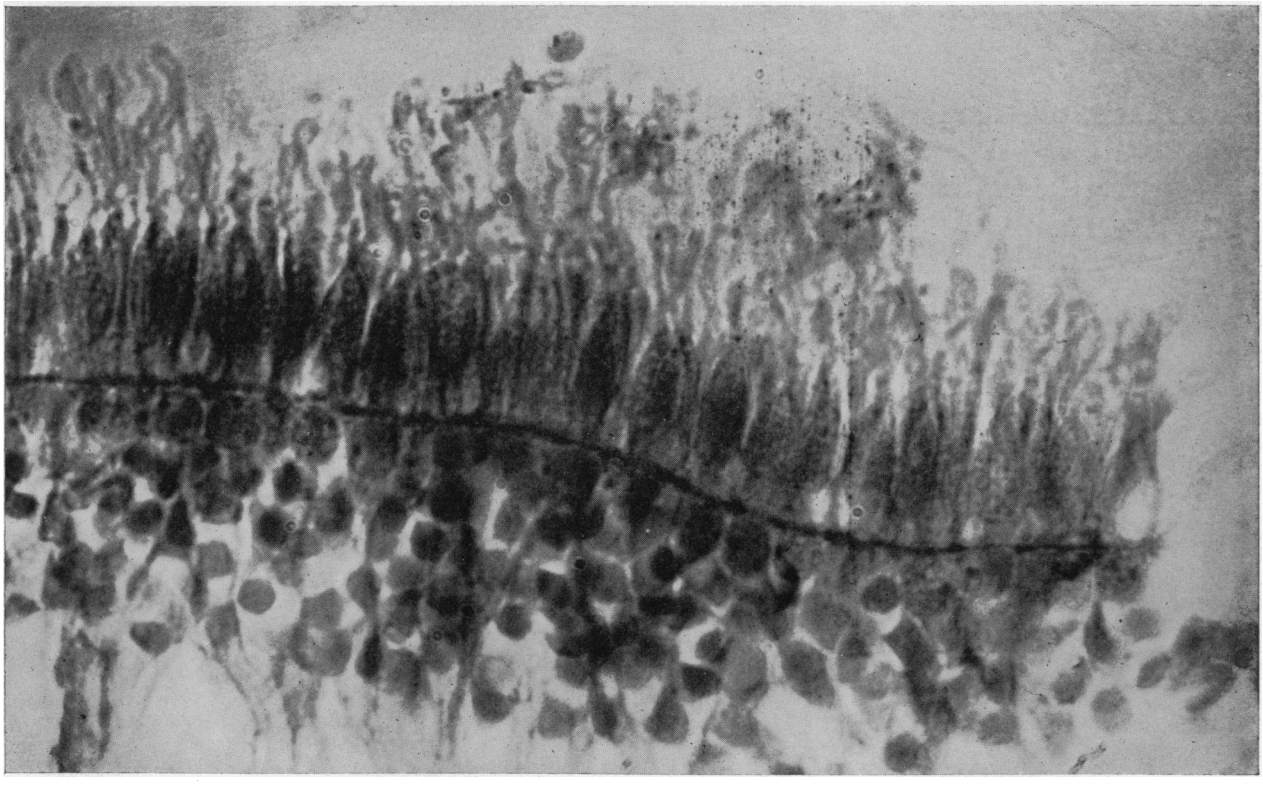
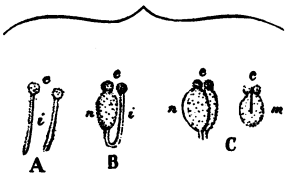


FIG. VI. HUMAN RETINA. OSMIC ACID PREPARATION. LOOPED EXTREMITIES OF CONES, AND NEAR THE CENTRE A TWIN CONE.



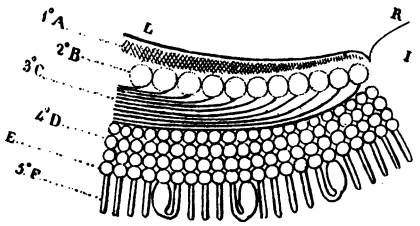


FIG. VII. PHOTOGRAPHIC REPRODUCTION OF PACINI'S FIGURES OF THE HUMAN RETINA.

Fig. VII is a photographic reproduction of Pacini's drawing of the human retina, from sections and teasings of the fresh unhardened retina examined in vitreous humor. The upper figure represents knobbed rods, a cone whose outer member becomes cylindrical and continuous with a rod, also twin cones. The lower figure is his diagrammatic view of the human retina.

Helmholtz, Czermak, Nuel, Wolffberg, Olshausen, Exner, and Dimmer all agree in describing a shadow or a mosaic work, like shagreen leather, made visible entoptically by rays coming through the pupil and moving in the same direction as the diaphragm which is held in front of the eye. Probably this appearance is due to the perforations in the external limiting membrane made by the rods and cones. This would prove that the percipient element must lie still further out towards the choroid, and the seat of light perception is therefore probably in the outer segments of the rods and cones, which, as is well known, are the only parts of the retina which are bathed in visual purple (rhodopsin).

We are all familiar with the effect of a diminution in the caliber of an electric wire or the substitution of a less good conductor in a circuit in which a strong current of electricity is passing, in increasing the manifestations of heat and light. It has appeared to the writer that possibly the rapid diminution in the caliber of the outer members of the cones and rods may have a similar function as regards the perception of light and the making of light undulations more palpable.

In conclusion, I desire to state that the negatives of all the photomicrographs which I have exhibited have been prepared by Dr. James Wallace. I think they are so excellent as to convince anyone examining them of his great skill as a microscopist and photographer.

DISCUSSION.

DR. J. E. WEEKS of New York. — I would like to ask Dr. Norris if he made his observations in specimens where the pigment layer was still attached to the retina?

DR. W. F. NORRIS. — The photographs show that they were made both where it was and was not attached. The loops show best where the pigment layer was detached. In many of the

photographs, however, you can see the outer segment of the cone or rod running up into the pigment layer and in some instances, veiling it so slightly that you can still follow the loop around.

DR. J. E. WEEKS. — The terminal parts of the rods and cones are so delicate that any interference with them may easily lead one astray. Has S. Ramon Y. Cajal, in his extensive study of the retina, made any mention of terminal loops? I have examined his work carefully, and, as I have not found mention of terminal loops, am surprised that such a careful observer should have failed to note such an important fact if it existed.

DR. O. F. WADSWORTH of Boston. — Dr. Norris's communication is certainly very interesting. Formerly I gave considerable study to the rods and cones, but I never saw anything like terminal loops where the rods and cones could be supposed to be in their normal positions. I must confess that, in the brief opportunity I have had to look at these photographs, I still cannot see them.

DR. W. F. NORRIS. — I have only to say that I have spoken of this matter with considerable diffidence, knowing that it was an extremely difficult subject, and that many able observers have worked over it with different results, and I should not have any hope of convincing this society but for the photomicrographs. If you look at these carefully and follow any one cone or rod up into the pigment layer you can convince yourself that the outer member of a cone in this situation curves and becomes continuous with the adjacent rod.

SPONTANEOUS RUPTURE OF THE CHOROID COAT.

BY ALBERT G. HEYL, M.D.,

OF PHILADELPHIA.

Spontaneous rupture of the choroid coat is one which occurs through the agency of forces set in operation by the eye itself, and differs from the traumatic rupture both in the direction of the tear and in the application of the forces by which it is brought about.

The patient, Barbara Bohner, æ. 65, applied at the eye department of the Episcopal Hospital Sept. 7, 1893. Has always been short-sighted, but less so in the R. E. than in the