Contributions to Physiological Optics
Johann Benedict Listing
1845

Rough translation of Beitrag zur physiologischen Optik. Johann Benedict Listing. 1845 (1808-1882), by Mike Simpson (www.SimpsonOptics.com). Mjs1@outlook.com.

Johann Listing was a colleague of Gauss, and this book is of particular interest because it is probably the first clear description of the “nodal points”, called knotenpunkte in German. He described them here for the eye, where the image is in fluid, and they were then collected into the 6 “cardinal points” of an optical system (though the first use is not known).

The nodal points were originally described over 175 years ago, but there is new interest in the 2020s because the nodal point of the eye is actually a useful reference for scaling the image on the retina, even though it was only originally defined for very small angles and flat surfaces. This is explored in the following publications, though it also appears to be generally either assumed or known:

Simpson MJ, Nodal points and the eye. Appl. Opt. 61, 2797-2804 (2022). https://doi.org/10.1364/AO.455464

Simpson MJ, Nodal points and the eye. ARVO Poster, Denver, CO. May 2022.

Simpson MJ. Scaling the Retinal Image of the Wide-Angle Eye Using the Nodal Point. Photonics. 2021; 8(7):284. https://doi.org/10.3390/photonics8070284

This is a very rough translation from German of Listing’s 1845 book, based on text from google translate, with occasional adjustments here and there. It captures the gist of the text, and it has been left like this to try to avoid misinterpretations. Interestingly, there was just a single television in the original translation (fernsehen, or distance vision). If anyone is interested in helping to improve the translation, please email.

The original version had very faint drawings on a single page at the end, but improved drawings were made, and they have been inserted into the text at the appropriate locations. The main interest is Sections 2-6, relating to the nodal points.

This version is the original 1845 printing from the following source: https://wellcomecollection.org/works/fvazxph9
There is also a 1905 printing that seems to be available from several sources, but perhaps they don’t have the drawings and images. This seems to have additional comments, and darker text. https://openlibrary.org/books/OL6965435M/Beitrag_zur_physiologischen_optik

There is also an interesting short biography of Listing here: https://mathshistory.st-andrews.ac.uk/Biographies/Listing/

Mike Simpson. Mjs1@outlook.com. www.SimpsonOptics.com. April 2022.   test

p3 Contributions to physiological optics

Johann Benedict Listing.

(With two lithographed plates.)

Few branches of physiology have { dermally} made such richer advances through the support of physics as the learning about vision and its functions. This benefit must appear all the greater, because at the same time our knowledge of the physiology of the other sense organs has been expanded. The help which physics has given physiology in the investigation of the sense of touch, taste and smell is slight. Substance, pressure, changes in volume and density are still very much friction, adhesion, capillarity, absorption, elasticity at the moment. Endosmosis, change of aggregate, changes in temperature and heat capacity, voltage and current of electricity are physical processes which, in addition to chemical actions, will only be given essential consideration in the future in the above-mentioned area of organic natural science. [newref4] Equally, this is the service that mechanics must have. and the acoustics of the doctrine of hearing are far from being sufficient for a theory of the functions of the ear. Quite different in the physiology of the eye. Here is the bridge between the organic and the inorganic science of nature has been built for some time, the anatomical and physical investigation of the constituent parts of the organ has often led to reliable interpretations, and has thereby given the method of measuring natural science an undisputed field. **[p4]** It is true that one will find this disparity a little less strange on proper consideration of the occasions through which a physical one in the various sense organs. Method in the research is conditioned. Obviously, in this perspective one can only speak between hearing and sight, in which the changes in the agents received from the outside world preceding the nervous affection are based on physical processes, just as the preparation of food for the purpose of assinilation is based on mechanical and chemical processes Influences, while in the other three sensory functions a similar stage of physical metamorphosis is not clearly pronounced. Unmistakably, however, the great inequality in the physical development of the doctrine of the eye and ear rests both on the unequal sum of anatomical and physiological facts obtained and on the various degrees of perfection of the physical theories in question. From an empirical point of view, this result seems less to rest on the greater interest, which the noblest sense instrument in the human and animal organism could certainly claim for itself, than on the objective difficulties observations and measurements of the auditory functions are connected. While in the eye the optical and mechanical comparison is the with **[p5]** the interpretation of most of the constituent parts has been established, and the whole construction of this instrument favors an experimental treatment both in life and in death to a large extent, our ears let us know the functions even the most essential members of the apparatus are still often in the dark. This relation is likewise exactly connected with the present state of the theory. Nature, according to the mere analogy between the vibrations of the ether and those of the ponderable media, would like to create two completely correlate sense organs, the dimensions of the ear would have to exceed those of the eye about a million times, and the acoustic apparatus would have the adventurous size of the inch-sized eye need to get nearly twenty cubic miles. Had we been apagogeic to the recognition of an essential difference in the structure and purpose of the two organs. Indeed, in addition to the common ability to distinguish the wave frequency in the most definite way, the ear alone seems to have a power of discernment for the speed change within each individual successive wave, and the eye alone for the spatial relationships of many simultaneously recorded wave systems, and one could not incongruously to call the ear a chronometer, and the eye a geometrical tool. Theoretical optics in its current state, however, leaves almost nothing to be desired with regard to its applicability to the investigation of the functions of the eye: in acoustics, for the part of theory which in the future determines to form a quite indispensable basis for the main functions of the

hearing seems, namely the Ermittelung? qualitative non-chronometric, that the theoretical development of the speed changes within a wave or the so-called waveform, even the beginning, can only be expected from the future.
So much so in these few indications, the further elaboration of which is reserved for another *golf occasio*n [**p6]** expected in the future. So much so in these few indications, the further elaboration of which must be reserved for another occasion, the attempt has been made to draw attention to the advantage which the physiology of the eye has gained over our knowledge of the other sensory organs and in particular of the dermal body, it was no more likely to induce an opinion than if the advances made in ophthalmology had left only a small number of questions unanswered. Aside from the general problem of specific nerve action, which pervades all sensory functions, the natural science of the eye still has a wide field open for experimental investigation, it may be concerned with the establishment of new kinds of phenomena, to which the present communication Example, or refer to the full explanation of facts which, like accommodation, have for centuries easier connection to the theory on the harvests are known. here the expansion of our knowledge will have an accelerating effect.

Section 1 1.

It is well known that there are such facial phenomena in which parts of the eye itself, or bodies more or less accidentally present in it, appear as objects and become perceptible, so to speak. This is where the so-called floaters belong, the blind spot on the retina undocked by Mariotte at the point of entry of the optic nerve, the vein shape in Purkinje's experiment, and so far they have mostly been included in the subjective facial manifestations, while they have been more appropriately counted among the objective insofar as the objects in their eye are essentially mediated by the external **[p7]** incident light hitting the retina can be seen. It would not, however, be inconvenient to separate these phenomena from the objective ones in the narrower sense, where the object is a short or considerable distance from the eye, and to assign the names of the entoptic facial phenomena to them. They then form a kind of transition group between the subjective and the really objective perceptions of the eye. The observations to be communicated here relate to a new phenomenon of this kind, and although their number is still very small and their detail is very different, so much seems to be allowed to be inferred from them, that in most eyes by far the breaking ones - are often afflicted with opaque places which, with regard to their shape and mutual position, have a high degree of immutability and are easily recognized by every eye, i.e. H. can be perceived entoptically.

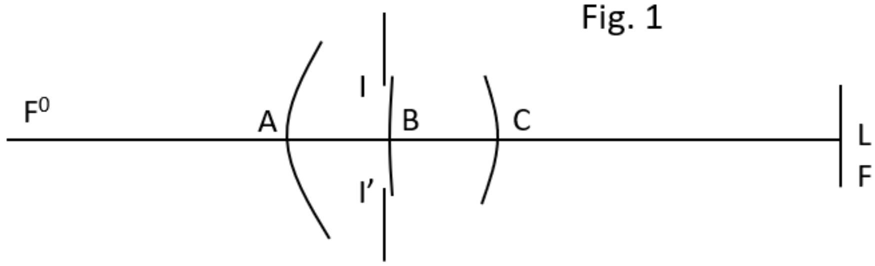
2

Section 2

We will start with a short discussion about the dioptric power of the eye, which is based on the paths that light rays take in the eye.

Human vision can, with sufficient accuracy for our present purpose, be compared to a system of three different strongly refracting media, which are separated by spherical surfaces whose centers of curvature lie on a straight line, the optical axis of the eye. In Fig. 1, the distance AL represents the optical axis of the eye, and A, B, and C represent the intersection points of the three surfaces. The point L is the retinal location that is illuminated by a ray transmitted along the axis. The clear aperture created by the iris is denoted by I to I’, and this is an almost circular opening that is concentric with the axis, called the pupil. The three surfaces A, B, and C are convex, convex, and concave, when going in order from A to L.

Fig. 1



[p8] Surface A forms the interface with the outside air and it is called the cornea. Surfaces B and C represent the anterior and posterior surfaces of the lens capsule. The material between A and B is the aqueous fluid, the second material between B and C is the crystalline lens that is contained by its capsule, and the third between C and L is the vitreous fluid. The indices of refraction of these materials lie between those of water and glass. The smallest index belongs to the first material, the largest to the second, and the third is only slightly larger than the first index.

In an eye set up for parallel light, all rays incident in the direction of the axis from a very distant point are combined at point L after three refractions. This point on the retina, located in the macula lutea, is therefore the back focal point of the system (MJS text not used: in the above-mentioned state of adaptation three refractive agents.) The intense power of perception causes the image of the object to be focused here by appropriate movements of the eye. Another focal point F^0, about half the diameter of the eyeball in front of the cornea, is the place in which collimated light parallel to the axis in the vitreous humor from L to C would focus after successive refractions at the surfaces C, B, and A.

Light rays traveling into the eye parallel to the optical axis behave like this. In shortsightedness, and for the eye that is accommodating to a near object, these two focal points have a slightly different location. The closer an object is to the eye, the more posterior to the retina the image is formed. With a weitsicthigen (wide?) eye, which only through a sammellinse **[P9]** perceives stars as point sources, the front focal point stands a little further from the eye, and the rear one falls behind the retina. During the changes in the eye that are brought about by adaptation, whose mechanisms are not yet completely understood, the two focal points move in the opposite sense. When looking at a near object, both move closer to the cornea. When looking at a distant object, both move further away from it.

If we place a plane normal to the axis through each of the two focal points, regardless of which of the various adaptive states of the eye it is in, we obtain two focal planes, an anterior and a posterior one. Apart from the spherical aberration or only those rays which are only slightly inclined towards the axis, rays of light travelling parallel to the eye will converge in the vitreous body and unite in a point at the posterior focal plane, and vice versa those rays which enter the eye from a point on the anterior focal plane, after having suffered triple refraction, move parallel to one another in the vitreous towards the retina.

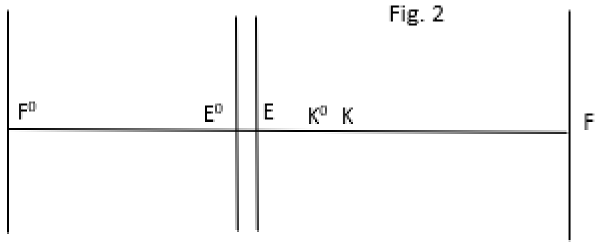
In a lens system, where the incoming and outgoing light travels in media with different refractive indices, as is the case with the eye, where the rays coming from the atmospheric air finally reach the vitreous body, in addition to the two focal points and their planes, four other points are to be considered, by means of which the rules for the construction of the paths and points of union of the light beams are very simplified before and after the multiple refraction. First of all, there are two points between the two focal points on the axis, to which we give the names the principal points (along with

Gauss [Note 1 p9]), and their planes, which are normal to the optical axis at the focal points, are given the name of principal planes.
[Note 1 p9. Gauss. Dioptric Investigations. P. 13.]
[p10] These points are located in the eye in the anterior chamber, between the first and second refractive surfaces. While their mutual distance is a few tenths of a millimeter, they both stand closer to the anterior focal point than to the rear, from about 2/3 to about 7/8 of the diameter of an eye that is accommodated for parallel light. [mjs. Is this from the retina?]

Two other points lie on the axis of the eye behind the two main points, which are called the nodal points of the directional lines [Note 1 p10]. Their distance from one another is always that of the principal points. The distance of the rear nodal point from the rear focal point is always the same as that between the front nodal point and the front focal point. The two nodal points occur very close to the rear surface of the crystalline lens, probably more often in front than behind.

Fig. 2 shows the mutual position of the 3 different pairs of points: F ° is the front, F is the rear focal point, E^0 the anterior, E the posterior principal point, K^0 the anterior, K the posterior nodal point, and it is always $E^0 E = K^0 K$ and $F^0 E^0 = KF$. Like the focal points, the principal and nodal points also change their places when the eye accommodates, and they are all connected. It is like a metal rod between F^0 and F connecting all 6 points, and in the region where it intersects the first surface (about 2 mm before E^0), lengthened or shortened in all parts by a change in temperature, could serve to visualize the displacements, but only to a lesser extent .

Fig. 2



[Note 1 p10. The two points, which Moser (Repertorium der Physik, vol. V. p. 372) calls the first and second principal points of the eye, are essentially different from the main points introduced by Gauss and are identical to the so-called nodal points here.]

[p11] the connected points suffer at the same time in the changes of the refraction of the eye. This rod (to speak in the same picture) from one or, without prejudice to the required symmetry of the two halves, would have to be thought to consist in parts of different metals, can of course not be specified as long as the adaptation elements are not exactly known. For the time being we can be content with making the displacement of each of the six points proportional to its distance from the anterior surface of the cornea.

Section 3 **3.**

The application and significance of the various points and planes discussed so far emerges automatically from the following constructions.

If in Fig. 3 there is a ray entering the eye from any direction (which, which is not indicated in the drawing, the axis is not contained in a plane), the position of the ray in the vitreous body can be found in the following way The incident ray hits the front focal plane at point (1), the front principal plane at point (2), travels parallel to the axis through (2), and hits the rear principal plane in (3). To continue the ray, a ray parallel to (1) and (2) through the rear nodal point is used, and this intersects the rear focal plane at (4). So (3) (4) gives the ray in the vitreous humor. Without adding a nodal point (4) could also be found through lines F^0 (5) and (5) (4), the first parallel to the incident ray (1) (2), the second parallel to the axis.

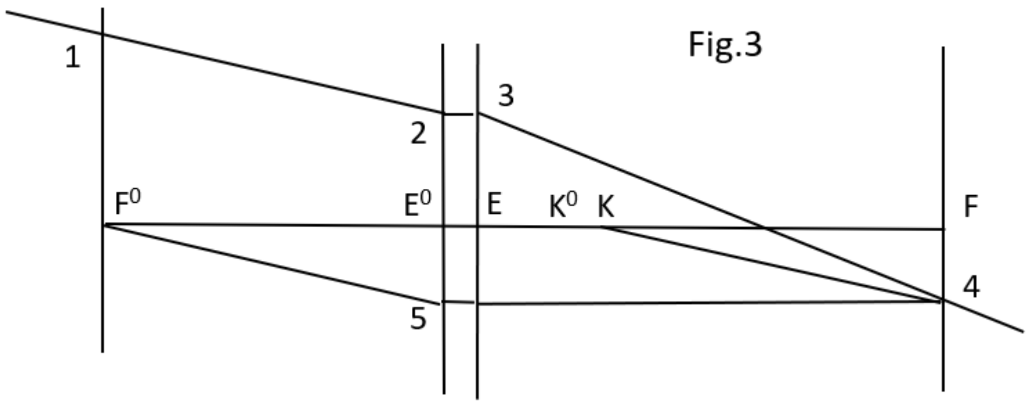


Fig.3

If there were a ray that extended beyond (2) through K °, [mjs, not the line in fig 3, but a different point 2 in fig 4) it would coincide with the line K (4) after the refractions suffered, ie. an incident ray aimed at the front nodal point **[p12**] results in a parallel ray leaving the posterior nodal point, or a ray directed towards the anterior nodal point moves in the vitreous in the same direction and appears merely displaced by the distance of the nodal points along the axis. The ray behaves as if it had passed through a plane glass (with parallel sides lying normal to the axis). Let us call the first ray the straight line which connects an object point lying in front of the eye at any distance with the anterior nodal point, the second ray is a line passing through the rear nodal point and parallel to the first ray. This is how what has just been said can be expressed as follows. A ray incident along the first directional line goes, after refraction, along the second directional line. This case is explained in FIG. 4, where DK^0 represents the first, KD′, the second direction line.

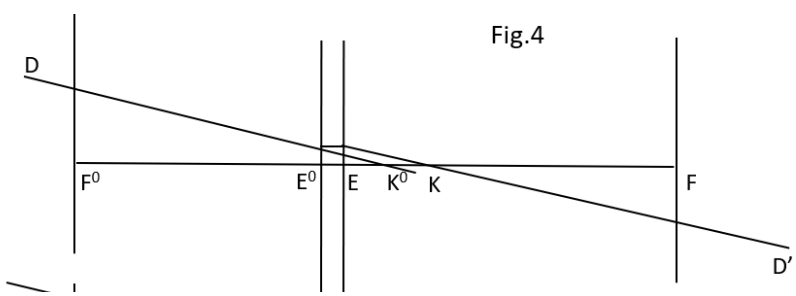


Fig.4

For a system of parallel incident rays, point (4) in FIG. 3 is common and all rays must unite in it after refraction, at the intersection of the second directional lines with the image lies in the posterior focal plane. If the eye is adapted to parallel light, it clearly sees an infinitely distant point source, and the image lies on the retina where the second directional line is directed is shown in FIG. 5, where the parallel points A, A ', A ", A" converge after the refraction at point B of the posterior focal plane. The nodal reference line is DK° and KD′, as in the previous figure. [mjs. Richtungslinien seems to be the reference line through the nodal points. Does it have a name in iEnglish?].

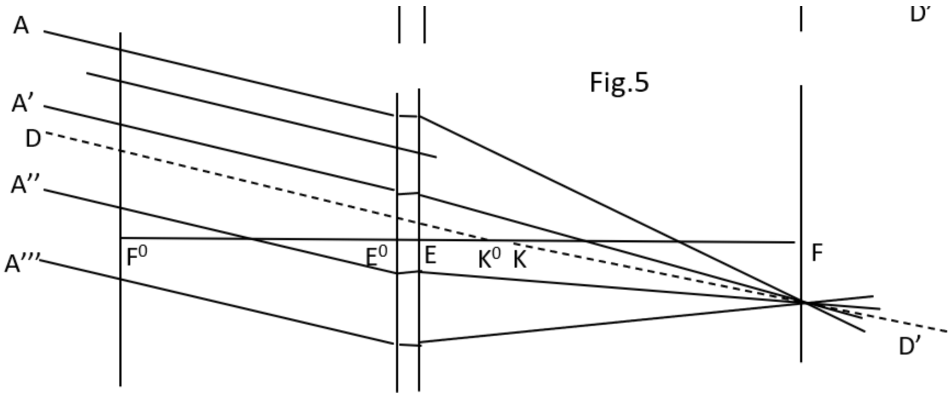


Fig.5

For a system of incident rays emanating from a point in the anterior focal plane, all exiting rays in the vitreous are parallel to each other and with the two reference lines. In Fig. 6, P is the point source, DK^0 the first and KD′ the second direction. The outgoing rays Q, Q', Q" and so on **[p13]** are all parallel with the latter. Their starting points, located on the rear principal plane, are, like point (3) in Fig. 3, according to the rule discussed above. The special case that was described earlier, where P was joined to F^0 and rays in the vitreous were parallel to the axis, are not interchangeable.

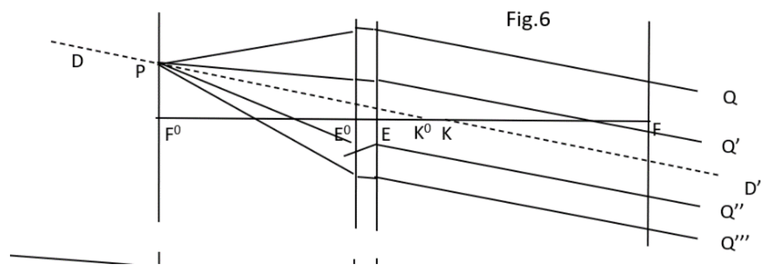


Fig.6

If the point source lies at a finite distance in front of the anterior focal plane (Fig. 7), then the rays converge towards a point on the second reference line behind the posterior focal plane, which is found when the construction discussed above in FIG. 3 is applied to an incident ray that is not parallel to the first reference line PK °. If the light source is outside the axis of the eye, connect P with F ° by a straight line, extend it to the anterior principal plane according to (5) and draw a straight line parallel to the axis through (5) so that the intersection point P of this latter with the second reference line is the real image (Note 1 p13) of P.

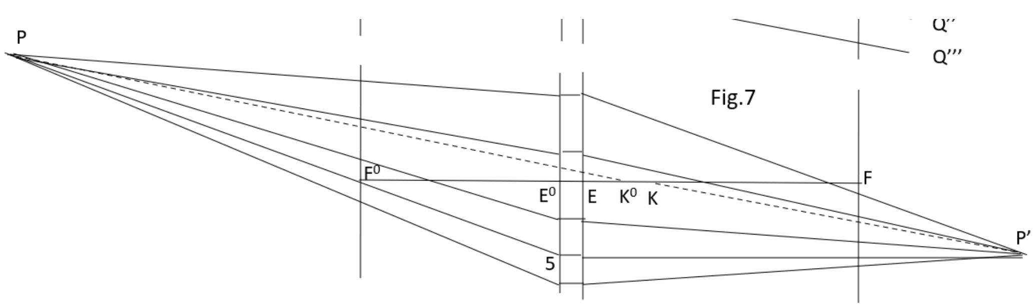
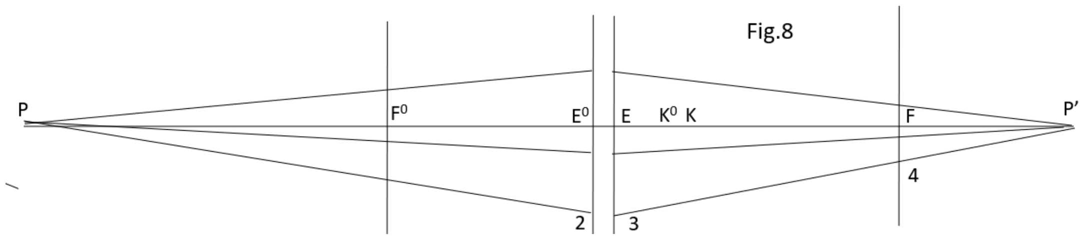


Fig.7

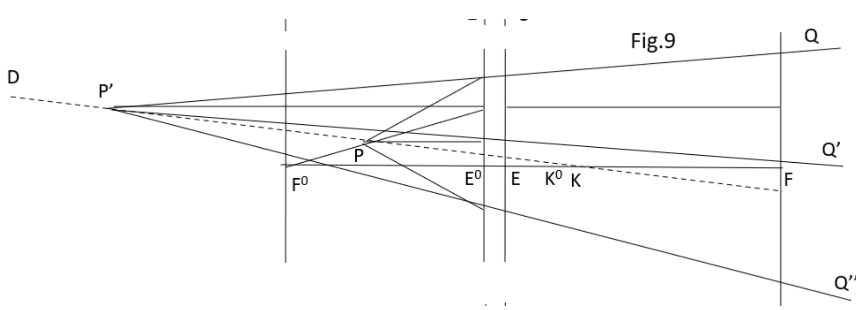
Note 1 p13. At a shorter distance, this image must be called real according to the language of optics itself in the case when the retina is in front of P′ and the rays in the vitreous do not really come together, *or one should not come from real images Talking behind the objective lens in the Galileo telescope and in front of the objective mirror in the Cassegrain telescope.*

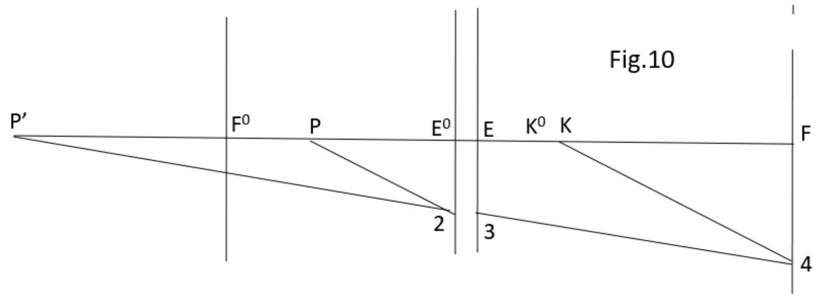
But if the point source is on the axis of the eye, then draw a ray (Fig. 8) P (2) inclined to the axis, determine the extending ray (3)(4) according to the rule given in Fig. 3 , then the intersection P of the same with the axis with which both directional lines now coincide will be the image sought. The distance to which the rear focal plane in front of the retina can be displaced by accommodation, the distance of point P from the eye is the smallest at which the eye can see clearly.



[p 14] The smallest distance of the point P, the image falls behind the retina for every possible refraction state of the eye, and the point P ceases to appear clearly. Such a limit for the approach of the point P during clear vision takes place for each eye. Even in very myopic eyes, it does not seem to be less than 5 centimeters (counting up to the front surface of the cornea!)[Note 1 p14]. If FP' were the smallest distance for the eye to be able to move the rear focal point in front of the retina by adaptation, then the distance of the object P from the eye would be the greatest at which the eye can still see clearly. According to my experience, there are short-sighted eyes of a small extent of adaptation, where this maximum of the distance of the object point P from the cornea is only 7 1/2 Centimeter. This situation is encountered only for the very shortest eyes.

Finally, if light emanates (FIG. 9) from a point P located between the eye and the anterior focal plane, the rays Q, Q ', Q etc. will diverge in the vitreous from a point P' lying on the second reference line KD, which is a virtual image of P. Its determination (as the figure explains by itself) takes place entirely in the manner mentioned in Fig. 7. Fig 10 (analogous to the 8th figure) represents the special case where P is on the optical axis.
~~in which a short-sighted. This limit is only found in Fig. 10, where pin the Ax lies.~~





Note 1 p14. A total anomaly is the case described by Hueck (the Bewegund og the crystalline lens, p7) of a so called microscopic eye, which only saw lines clearly in the interval from 8 to 28 par.

Section 4 **4.**

Taking into account three successive refractions in the eye, the constructions in the previous Figures. give the exact geometrical relationships between **[p15]** the incident light rays and the rays of light passing through the vitreous. You will, when future measurements, learn more precisely [Note 1 p15] the mutual distances of the optical points discussed and their changes in location depending on the accommodation, which form an essential part of the theory of monocular vision. The first nodal reference lines drawn from all off-axis points of an (extended) object, are the directions of vision for indirect vision. The apparent position of the objects present in the field of vision with an unchanged position of the axis of the eye is that which an eye of infinitely small dimensions located in the front nodal point would observe, and in the same position the retinal images should appear to such an eye from the rear nodal point, only in directions which differ by 180 degrees from the viewing directions. If, in direct vision, we lead the axis of the eye successively to all points of the object, then the standpoint of that infinitely small eye is to be taken at the point of rotation of the eye determined by Volkmann, which lies at about 1/5 of the eye diameter behind the posterior nodal point. The line of sight, a straight line drawn from the point of rotation of the eye to the object, into which, in direct vision, the axis of the eye must be displaced by the muscles while the eye socket is not moved, is therefore an indirect object seen is almost exactly different from the first line of direction, and the angle between the two is the parallax between the apparent position of the objects at direct and **[p16]** indirect vision, caused by the eccentricity of the anterior nodal point in its position in relation to the mechanical center of the eye [note 1 p16].

[Note 1 p15. The information given above should only serve as a casual illustration of these relationships, which is sufficient for the present purpose. I will on another occasion try to combine the numerical elements as they follow from previous experience in a schematic or a so-called middle eye.]

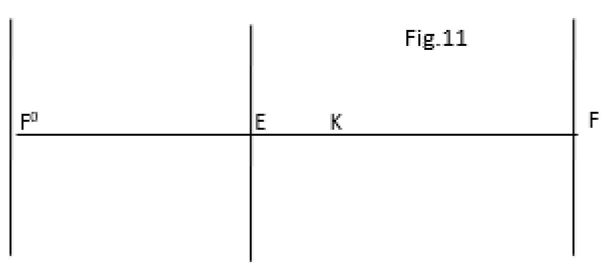
Section 5 **5. (on p16)**

For most cases of application the simplification of the presuppositions is sufficient to think of the eye as consisting of one homogeneous and isophane means, and it is now not difficult, according to what has been said, to determine the exact determinations to give this simplification. The lens has usually been left out of the eye without changing the corneal surface, and the refractive medium has been given such a large refractive index as is necessary to set the rear focal point near the yellow spot on the retina,

[[Note 1 p16] its amount in minutes of arc is equal to the ratio of the number 1719 to the distance of the object from the eye, expressed in centimeters, multiplied by the sine of the elongation of the indirectly seen object from the axis of the eye, measured at the point of rotation. For an object 25 centimeters from the eye e.g. is found at the following elongations from the axis:
at 5 degs 0 parall. 6'0
10   11.9
15   17.8
20   23.5
25   29.1
It is zero for objects in the axis at every distance and for objects at an infinite distance in every elongation. This parallax refers only to objects in the horopter and is to be differentiated from that where, when the eye is rotated by shifting the pupil from the first directional line, a deflection of the (indistinct) image from the second directional line of every object not lying in the horopter. According to this, the experiment cited by Brewster (Phil. Trans. Of the Roy. Soc, of Edinburgh vol. XV. Part. III. P. 351) and the argumentation attached to it must be assessed.]

[p17] an index that is greater than the strongest one found in the eye through observations, namely the nucleus of the crystalline lens, even stronger than that which must be attached to the entire lens, which is considered to be homogeneous. For the time being, of our six optical points, only the rear focus retained its previous place, and the other five must suffer major dislocations. If it is in the nature of the simplification to be introduced here that both the two principal points and the two nodal points coincide in one point each, then that transmission must be natural from a dioptric point of view where the changes in location are the least possible. So we leave the distance between the two focal points unchanged and combine the pair of principal points and nodal points each into a single central point. The dislocations are then smaller than the observation errors inevitable in the experimental determinations. The principal point thus created retains the same distance from the front focal point as the nodal point [Note 1 p17]) from the rear focal point. As a result of the adaptation, the four points must also suffer similar shifts as those mentioned above (Fig. 2??? Art??). This scheme of four points corresponds to a refractive means, separated from the surrounding atmospheric air by a spherical convex surface which intersects the axis at the principal point and whose center lies at the nodal point. Let in Fig. 11 F^0 and F, as before, be the focal points, E the principal point and K the nodal point, then in approximate round numbers $F^0E = KF = 15$

Fig.11



[Note 1 p17] This node point is , according to its optical meaning, completely identical to the Volkmann Kreuzungspunkte (mjs cross point? No, intersection) ~~between the two intersection points, and you like it,~~ if you want to ignore the reference to the two nodal point of the more precise theory, henceforth call the intersection point, even if the point in the eye determined by Volkmann still needs to be corrected. 9mjs needs mor work).

[p18] millimeters, EK = 5 millimeters. be set. The refractive index of the medium (equal to the ratio of the distances of the main point from the rear and front focal point) is thus equal to that of the water; the curvature of the anterior border of the eye must, however, be increased in the ratio of 5 to 8, and its cross-section with the axis of the eye by about 3 millimeters. be moved backwards.

How the constructions presented in Section 3 are simplified under the present assumption can easily be found without further discussion, and it suffices here to point out that as soon as the principal points and the nodal points unite in one point, so too the two principal planes in one principal plane, furthermore the points designated in FIGS. 3, 4, 10 with (2) and (3) in one point, and finally the first and second reference lines coincide in one reference line.

The line of direction in the obstruction now is a straight line drawn from the object point seen (directly or indirectly) through the nodal point of the eye. The real or virtual meeting point of the light rays running in the vitreous lies on it. If the object point is in the horospter or at the distance of clear vision due to the state of refraction of the eye, the image lies on the intersection of the reference line with the retina. If the object point is on either side of the horopter, the retina receives inconsistent rays distributed over a surface, and the indistinctness of vision depends on the degree of this defocus, proportional to the area of the irradiated area. If we understand by visual direction or line of sight, in the simpler preselection now made, every straight line drawn outward through the nodal point from an optically excited point of the nerve membrane, then in horopter images the visual direction necessarily fills the direction line, but with images from **[p19]** objects other than the horopter only when that ray of light which passes the middle of the natural or artificial diaphragm delimiting the rays passes through the nodal point at the same time. The explanation of the well-known experiments by Scheiner and Young is based not only on this, but also of the increase or decrease in the apparent size of objects on this side or on the other side of the horopter, when viewed through small openings [Note 1 p19].

Section 6 **6.**

If we have deduced the path in the vitreous between the last separating surface of the three media of the eye and the retina from the incident rays given up to now, then we still have to consider those paths which the light radiate in the means located in front of this last separation surface, d. H. in the aqueous moisture and in the crystalline lens. Such a consideration has been passed for stable lenses. The analysis of most of the objective as well as of the subjective facial phenomena is only of subordinate importance. Our present purpose, however, where an entoptic phenomenon is concerned, may seem suitable for a development of this part of the dioptrics of the human eye in constructive form to arrange. There would be repeated successive application of the interest.

[Note1 p19] In his work, Contributions to the Physiology and Physics of the Human Eye, Burow overlooked this last circumstance in his method of determining the point of intersection (p. 85) and was thereby led to the erroneous conclusion: that the point of intersection lies in front of the cornea, and

that its distance from it is a function of the elongation of indirectly seen objects (p. 91, 92). If the author had given his observation numbers, the correct result could probably be derived from them.]

[p20] regulations become necessary according to which the refracted rays can be derived from the incident rays in the case of a spherical interface between two media of different refractive constants, regulations which result essentially from the rules discussed in Section 3, if one the requirement introduced in the previous sections applies to them. Because of the very slight difference between the refractive ratios of the first and third means, one could allow oneself to view the crystalline lens as being surrounded on both sides by equally refractive media, and the rays passing through the first separating surface (the cornea) as being through one Assume a biconvex lens with a falling refractive index which corresponds to the transition from the neighboring medium into the lens substance. However, it is precisely this approach, which has been variously used to calculate the merging distance of the rays running in the vitreous, that the most important deflection of the rays takes place at the first separating surface, and that the lens changes so little in the convergence of the rays causes that in this respect too the simple hypothesis of the preceding kind is perfectly adequate for most cases. If, because of its layered structure, we must also attach a higher refractive index to the lens, if we want to regard it as a homogeneous medium, than the largest found by Chossat for the nucleus of the same [Note 1 p20], the necessary relative index remains the'

[Note 1 p20) On this occasion it may be remarked that here lies the simple, so often misunderstood solution of the riddle, which one has long since found in the great difference between theory and experience with regard to the range of union of the refracted rays in the eye. In completely new physiological writings, which treat this subject in an awkward manner, the lens regarded as homogeneous is assigned the relative index 1.0350 and then searches for the contradictions which result from this violation of optics by the most artificial means lacking all physical and physiological support *(this was also on p21, not scanned. Through the knowledge??, all physical and physiological middle to heben?].]*

[p21] crystalline lens must still be set below the number 14/13, where the passage of the light from the atmosphere into the substances surrounding the lens of this ratio greater than 4/3 (approximately 103/77), and the differences in direction before and behind the second and third surfaces of separation, even for the marginal rays, when the pupil is wide open, the deviation can be neglected in our case without considerable error, especially on such short distances (of hardly 5 millimeters). We therefore consider the elongations drawn backwards to the front surface of the cornea of the rays running in the vitreous body, after their paths have been determined according to the prescriptions conceived in the preceding section, as the paths which these rays take in the anterior chamber and in the crystalline lens.

Section 7 **7.**

To shorten the term in the following, a system of such rays of light, which are all parallel to one another, or which all diverge from one point, or converge towards a point, may be called homocentric light. So it is under this name z. B. conceived the parallel light of a fixed star or a certain point of the sun or moon disc, further that of a certain point on the surface of every luminous or illuminated body, or that of a clever point of immeasurably small dimensions, or that of Light diverging at a certain point of a real or virtual image created by lenses or mirrors, and finally rays, which arise with the application of catoptric or dioptric, **[p22]** means converge towards a real image point. As a system of homocentric light we often encounter in nature and in optical experiments a totality of systems of homocentric light, the centers of which are distributed over a surface or in a physical space, sometimes of lesser, sometimes of greater extent. Sunlight is an aggregate of systems of parallel light, the centers of which lie on a circular disc of 32 minutes of Kleifung? [Note 1 p22] and therefore offer directional differences of up to 32 minutes. The smaller is the maximum of the differences in direction which occur at a given place under the rays passing there, the closer the aggregate of homocentric systems will approach a single system. In many cases the light from such planets, whose diameter lasts up to 3 minutes, can be regarded as just as simply homocentric as that emanating from a fixed star 2), and for the present physiological purpose there are deviations from the exact one Homocentricity of a much larger amount is permitted.

[Note 1 p22) as much as "apparent diameter, apparent or angular size."]

[Note 2 p22) A case where this equation is not permissible is offered by the well-known explanation of the sparkle given by Arago, based on the undulation view, of the Fixed stars.]

Section 8 **8.**

If homocentric light falls into the eye, the center of which is in the vicinity of the anterior focal plane, the rays of light running inside the eye will also be homocentric but almost parallel. The rules contained in Sections 3 and 5 give us in each case, in a special case, information about the position of the center of the light beam in the eye. If the point source lies in **[p23]** a short distance in front of the anterior focal plane, the inner rays receive a slight convergence and the center or the real point of union lies at a considerable distance behind the eye. If the point source is close behind the anterior focal plane, the inner rays receive a slight divergence and the center or the virtual merging point lies at a greater distance in front of the eye.

This distance becomes infinitely great, or the homocentric light passing through the refractive media of the eye becomes parallel when the point source in front of the eye lies in the anterior focal plane itself. Various means are at hand for producing homocentric light of considerable union within the near the front of the eye. The light source to be brought into the focal plane can consist of a very fine opening of a screen held 1 or 1.5 centimeters in front of the front surface of the cornea, which allows light of the same intensity and color as possible from a sufficiently extensive light background to pass through. The screen can be a thin blackened sheet of metal. The openings can be made by means of a fine sewing needle, the point of which is allowed to penetrate the screen, which is lying on a smooth surface of hard oil, only as deeply as is necessary to pierce it. In this way, you can easily create small holes, whose widths can be 1/6 to 1/15 mm. The largest of about 1/10 mm can be recommended as sharp and expedient. As a background during the day a blue sky or an evenly cloudy sky, a white wall or paper surface illuminated by the sun can be used. In the evening, every bright screen that diffuses the rays of light (such as milled glass, frosted glass, thin or oiled paper), which can be seen at a short distance behind the opening containing the opening can be used. **[p24]** This can be done by holding a dark shade and illuminating it brightly from the back by one or more candle or lamp flames brought close as required.

Furthermore, every real or virtual, both dioptric and catoptric, very reduced image of a luminous object of small size on a dark background can be brought into the necessary proximity before the eye. For example, the small virtual mirror image of a light flame on a strongly convex point of the smooth surface of a finger ring, on a foil-coated glass bead, on a small needle button made of dark glass and the like can be used for this purpose. The mirror surfaces themselves, since the virtual images lie behind them, must be brought closer to the eye the less their curvature is. The virtual image of a small luminous object behind a diverging lens with a short focal length can also be used. The real images produced by strong converging lenses (microscopes) or by concave mirrors with a small radius of curvature grant the advantage of being able to be approached to the eye at will without the risk of disturbing physical contact, yes, one can by using real union points relocate the center of the incident homocentric light into the interior of the eye or behind it, which may be of interest in special cases which, however, are not to be considered here. Finally, several of the means mentioned can be combined with one another in such a way that, in the manner of other optical tools, real or virtual images can be repeatedly used as objects to produce new images that are as small as possible. A telescope or microscope can be used, on which you change the distance of the lenses and swap their places.

Although the last-mentioned more artificial devices can offer advantages under special circumstances, the above-mentioned is very sufficient for the main purpose. **[p25]** -fold means, consisting in a dark screen with a very fine opening, not only completely, but also mostly deserves the advantage over them, insofar as it is free of some, difficult completely with the use of lenses and mirrors is to be avoided, bad conditions, which can significantly impair the purity of entoptic phenomena. I was therefore allowed to limit myself to brief indications here in the indication of those more complex remedies, the details of which are known to every knowledgeable reader.

In order to estimate the magnitude of the deviation from perfect homocentricity of the rays of light running inside the eye in the event that a screen with a small opening is brought into the anterior focal plane of the eye, we equate the distance of the anterior focal point from the nodal point 20mm and the width of the opening, as mentioned above, is equal to 1/10 mm, the parallel light running in the eye behaves like that of a luminous star of the same apparent diameter with the small light disc measured from the node in the front focal plane, i.e. from about 17 minutes or a little over half of the sun's or moon’s diameter. The deviation of the homocentricity is therefore about 0.3 degrees, which in our case can be completely disregarded. When the screen is moved closer to the eye, this deviation becomes larger according to the measure of the reduction in its distance from the nodal point and, if its influence should be taken into account, it would have to be calculated separately for each particular place in the eye, insofar as the light no longer applies becomes parallel but divergent, a calculation which easily results from the rules given in Sections 3 and 5 by itself. The deviation is greater here, the further forward in the eye the location under consideration is located.

It should be noted here that **[p26]** from the mentioned deviation from homocentricity, or the greatest directional difference among all rays that reach a given place from a circular light source, a measure for the imperfection of homocentricity is found, if one squares half the diameter of the luminous circle, expressed in arc minutes, and divides it by the number 47 272411, the unit being based on the complete omnipotence of the incident light, as it would take place inside a luminous hollow sphere. For our above case of a deviation of 17 minutes, the measure of the imperfection of homocentricity would be about one and a half millionths. ·

Section 9 **9.**

Let us now pass to the entoptic phenomena in the homocentric almost parallel light.

First we see a moderately lit, almost circular field, the shape of which is determined by the pupil, the so-called circle of confusion. Most eyes notice, at least with a little attention, small irregularities in its circumference, which often cause only slight, but sometimes more noticeable, deviations from the circular shape and give the border a wavy, angular, or indented appearance. This circle-like shape of the circle of confusion is an exact image of the circumference of the pupil and it is self-evident from what was said in the 5 article about the directions that we have our pupil in the opposite position, i.e. H. Turned 180 "in its plane, see in the horopter, so that (as diseases, malformations or injuries to the iris can produce similar cases) an eye with an A-shaped pupil perceives the field of confusion in this form V entoptically. That which surrounds the circle Dark is the one that would take.

p27 Effect of the hard shadow which the opaque diaphragm, or the iris together with the uvea, casts on the retina in homocentric light. If one were to determine the apparent size or the size of the circle of confusion, one would ask to draw the lines of sight through the nodal point and that of them from two diametrically opposed points of the cast shadow of the pupillary rim falling on the retina to determine the formed angle. If, for example, we set the distance of the nodal point from the macula luteà in one eye, then in the parallel line for every millimeter in the diameter of the pupil the circle of confusion is 3 ° 50 ', e.g. B. for 4mm pupil width 15 ° 20 '.

The well-known change in the size of the pupil can very easily be perceived entoptically in the changes in the structure of the circle of confusion. If one shortens the range of vision by adaptation, the pupil is reduced, incidentally, under the same circumstances, and vice versa. Eyes of practiced disposition will recognize these changes as occurring almost simultaneously with the act of will 15 mm below, similar to the movements stabbing under the direct influence of will. If, furthermore, the intensity of the light falling on the eye is changed without any arbitrary influence on the state of accommodation (e.g. by means of lateral screens or by changing the light source itself), the pupil dilates with decreasing light intensity and vice versa. Finally the consensual reflex movement of the iris can be comfortably observed, which is caused by the influence of the change of light on the other eye. If one suddenly opens the other eye, which was previously closed, one perceives a lively narrowing of the pupil, and on the eyes of the other eye an enlargement immediately ensues. Cause and effect are separated from each other by a measurable time interval, and the course of the two opposing

p28 courses seem to be significantly different. In the eyes, the narrowing usually begins 0.4 of a second after opening the other eye; it lasts about 0.2 seconds. and goes beyond the final position, which the pupil then only over-reaches through a slight dilation lasting several seconds. expansion occurs after about 0.5 sec., takes 1 to 2 seconds. and at the beginning quickly, then gradually, more slowly, without going over into narrowing oscillating, the equilibrium expanse. In this experiment the closing and opening of the other eye is more expediently effected by closing the other eye with the hand or an umbrella than by the songs.

The drop shadow of the pupillary edge and thus also the cladding of the circle of confusion becomes larger or smaller than with parallel light, if the light in the eye is divergent or convergent due to slight displacements of the light source on this side or on the other side of the front focal plane. If the position of the light source in relation to the anterior focal plane and the size of the pupil were given, one would determine, according to the rules given earlier, the center of the homocentric inner light lying backwards or forwards, and then by light construction the size of the drop shadow of the pupil on the retina and the cladding of the circle of confusion, whereby the distance of the shadow-casting edge of the iris from the retina may be assumed to be approximately 20 mm.

The sharpness of the delimitation of the drop shadow in the optical sense is tens, i.e. H. from the deviation of the imperfect homocentric light passing through the eye. In the case of a deviation of 17 'discussed in the preceding Art., The width of the half-shell with a diaphragm deformed 20mm from the retina is almost 23', and thus about 40th part of the diameter for a 4mm wide pupil depends on the width of the half shadow

p29 sers of the circle of confusion. The clarity of the limitation - physiologically taken from the imperfection of homocentricity, as one can easily convince oneself of it by the experiment with larger openings held in front of the eye. In the case of circular light sources, however, the obscurity is much smaller than the width of the penumbra. The eye counts a considerable part of the penumbra in the light field, a small part of which depends on shadow spaces, and only a small remainder causes the obscurity of the shadow boundary!).

Although the vagueness of the shell delimitation resulting from the imperfect homocentricity of the light is only a few minutes, the sharpness of the shadow on the retina intended for the present purpose suffers a multiple entry from another side. However, the associated histological irregularity of the refractive media is more appropriately taken into account in the appearances to be observed later in the scattering field, and the disruptive influence of physical moments, as diffraction and other interference effects, which will be a rich material in the future special investigations can be made, if not entirely eliminated, but very much reduced by the choice of suitable means. It is assumed here that only moderately strong light sources are used, which emit rays of the same strength and color in all directions, and that one especially avoids the intense sunlight which produces the most complex interference spectra.

Note 1) With this situation, the further pursuit of which must be reserved for another occasion, both the very slight (apparent) darkening of the moon, which is almost entirely in the penumbra, and the continuous excess of the observed full shadow depend on the lunar eclipses over the theoretical close together.

p30 **10.**

The size of the circle of confusion, which appears in the field of vision and can only be perceived through indirect vision in all its parts at the same time, is greater than the angle at which, with the light source in the stationary position against the eye socket, the axis around the The point of rotation is rotated when we pass through a diameter of the circle of destruction from one end to the other visually. Or, in other words, the part of the sky directly visible through a fine opening in the front focal plane is smaller than the part seen indirectly.

If we stick to the case of the previous article, where the apparent diameter of 15 ° 20 'has been found for a 4 mm wide pupil and parallel (internal) light, we find the diameter of the part of the sky which can be reached by vision or direct vision only 9 ° 21 '. if we visualize the circumference of the circle of confusion, its center moves in a circle, the radius of which is 3 ° or almost 6 lunar widths. The center of the movement lies between the point of the circumference directly viewed and the center seen indirectly (to be estimated by eye). Every movement of the point of vision in the field of vision produces an opposite movement of the whole circle of confusion. Ratio 64 100 smaller than the former. The parallax contained in these movements, which must not be confused with the other parallaxes mentioned earlier, depends on the mutual relation of four quantities in the eye at the same time, namely on the distance of the pupil from the retina and the retina three distances of the knot point from the retina, from the anterior focal point, and from the mechanical millimeter of the eye).

Note1) Let us denote these four Gröfson in the stated order rest on p31

p31 It is easy to convince yourself of this parallax by attempting to measure the movements in question on a distant field with unchanged position of the head and the light source, which is measured with fixed points serving as markers or lines. For this purpose the screen with a fine aperture and a strongly illuminated paper covered with dark lines can be used to form the background, or, what is even more convenient for this purpose, the image of a candle flame and a mirrored image of a candle flame on a small ball (glass head of a needle) dark background with light dots or lines.

In the following considerations we will disregard the mobility of the whole circle of dispersion just discussed, and the objects that are somehow perceptible in the field of light not on fixed points in the sky or on a background, but on certain points of the disintegration

Note from p30 cont: through a, b, c, d, then (with a sufficient approximation in most cases) is the ratio of the movement of the entire circle of dispersion (ab) c + ad to the movement of the point of sight.Since 6 bc is always smaller than a, this ratio is always negative, d. H. one movement is opposite to the other. If we set a = 20, 6 = 15, c = 20, d = 4.6 in millimeters, the value given above - 0.64 results for this ratio. The movement of the point of sight between two definite points of the circle of confusion is related to the clot between the two points, when the point of sight bc is at rest, as to unity. For the numerical values given, this ratio is 0.61, and the directly visible part of the sky is related to the indirect, like 37 to 100. Moods are based on the assumption that the light source is in the front focal plane and the eye adapted for parallel external light. For moderate deviations from this, the process is essentially the same and only different in numerical terms. A more general development, however, as much as it would be of interest for other questions, can rightly be dispensed with in our present considerations.

p32 within the scope of distribution yourself. Even if we are initially only dependent on the measure of the eye and the art of comparison during indirect vision, insofar as we cannot equip the diaphragm in the living eye with a network of threads as in the telescope, a moderate exercise is usually sufficient here Skill off. First of all, the middle point of the circle, which can be easily identified by estimation, is to be regarded as such a fixed point. Through it one easily draws a vertical and a horizontal diameter in one's mind. Furthermore, the circumference can be used, as it were, as a circular micrometer in addition to this imagined crosshair, although the changes discussed in the previous Art, which result from the enlargement or narrowing of the pupil, must not be neglected.

11.

If we bring a small body into the effective cone of divergent homocentric light located between the light source and the cornea, a cast shadow of it must appear in an upright position on the retina and the body will appear in an inverted position, as it were, silhouetted in the circle of confusion. The well-known experiment with a pin can be carried out with a glass micrometer, with woven materials (such as bobbinnet and the like) with organic objects (such as wood cuts, insect wings, etc.). In the same way, the eyelashes and even the eyebrows of our own eyes become visible. Fig. 12 shows the eyelashes of the upper eyelid perceived in the circle of confusion. The lower part of the light field is darkened by the lowered eyelid itself. Which stretches down between jo two eyelash hairs over this shadow space. Thick streaks of light are caused by the scattering of the light p33 on the surface of the tear moisture on the edge of the eye, which is strongly concave due to capillarity. With an intense light source, these stripes of light emerge very sharply and in significant elongation downwards, in sunlight at the same time with irregular but brilliant dispersion and interference effects. If the drawing is reversed, the enlarged image of the part of the upper row of eyelashes in front of the pupil 1) is in its natural position. It is this eyelash image that we often perceive for a moment with telescopes or microscopes by quick and unconscious blinking or by bending the eyelash hairs on the eyelash mount, and which not infrequently disturbs the inexperienced in the use of such tools. I thought I could mention it here in order to warn the inexperienced observer against confusing this appearance with entoptically seen internal objects of the eye. measured opening of the songs or by turning the head slightly backwards.

12.

The kind of phenomena mentioned in the previous article (of objects between the eye and the light source) put aside, we now perceive different, partly changeable, partly persistent objects in the field of dispersion in homocentric, almost parallel internal light. The variable ones recur in almost all eyes in a similar way, just as often as irregular; the persistent ones, which should preferably claim our attention, offer great differences in several respects in different eyes. We shall first consider the former, but only so far as to the case of

Note 1) my own left eye. 3.

p34 A proper distinction between them and the latter seems necessary

, the so-called flying mosquitoes (myodes, 1. muscae volitantes, mouches volantes) are among the variable phenomena. Preferably to be counted here are the individually and sporadically occurring, the orderly grouped together and the small circular discs strung together to form pearl-string-like filaments with a light interior and a dark contour surrounded by diffractory rings of color when the light is intense. The duration of the individual pearls varies from 3 to 8 minutes, and most are 5 to 6 minutes long. These scotomes, which in recent times have often drawn the attention of physicians, physiologists, and physicists, must, as they appear in diffuse and homocentric light almost in the same way and only slightly different in frequency, of entoptically perceptible ones originate from organic structures which are located at a very short distance from the retina, be it between it and the iliacid, be it in sack-like sections of the rearmost layers of the vitreous body. A great variability in the mutual position of your groups would represent constituents in all dimensions of space. Their changes of location in the eye, however, are very limited, as must be inferred from the easily observable peculiarity that in the field of vision they are always close to the same direction Move the sight points, so change their elongations only a little. They are seen from almost all eyes, only in very different numbers. A sudden turning of the eye, turning of the head, or other violent movements are often able to change their grouping and their position in relation to the central part of the retina very noticeably, while again not infrequently one eye can change the same group for hours or days and even for years only variability itself is very different. 50 &

p35 little changed looks 1). The investigations into the location and the physiological significance of these structures have not yet been concluded, and the more detailed discussion may be given here, where attention should only be drawn to the occurrence of these easily recognizable scotomes in the circle of dispersion of homocentric light - specifically referred to by Brewster 2). osly.

2. The phenomena resulting from the natural wetting of the cornea. With repeated closing and opening of the eye we often perceive the uneven distribution of the tear moisture, which by capillarity and viscosity adheres to the smooth surface of the cornea. In the experiment mentioned in Art. 11 one can easily observe, by small movements of the half-lowered eyelid, the bulge-like build-up of the viscous moisture on the banded strips or water lines, which immediately after the displacement at short distances from the The edges of the eyelids appear and immediately, depending on the degree of mucus content of the moist coating, disappear again through gradually more uniform distribution. This phenomenon is shown in the lower part of the circle of confusion in Fig. 13, as it can be observed with the eye very quickly opened. Furthermore, one sees in the light field often after blinking cloudy and indefinitely faster or slower delimited lighter and darker areas, which usually have a.

Note 1) J. 1780 Mcister reported a case of 24 years of persistence of similar Scotomo. The more conspicuous had, as his information shows, a size of 7 to 8 minutes (Göting. Magazin für Wissensch. U. Litt. Volume 1, piece 4, p. 131.).
Note 2) Brewster, on the optical phenomena, nature and locality of Muscae Volitantes; with observations on the structure of the vital humor, and on the vision of objects placed within the eye "in Trans. of the Roy. Soc. of Edinburgh vol. XV, part II, pag. 377. See also Ructe's textbook der Ophthalmologice p. 145. SO

P36 self-indulgent movement from top to bottom, but often increasingly blurring and disappearing. originate from very small inequalities in the thickness of the moist layer and the dependent wave-like distributed non-uniformity in the refraction of light on the corneal surface. Finally, one often perceives light points like drops of water, surrounded by a larger or somewhat darker halo, which, when the eye is opened, usually move very quickly downwards in the field of diffusion. They arise from capillary accumulations of the moist layer all around and on individual clumps of mucus or mechanically mixed in, strange fine bodies, dust particles, etc. The local meniscus-like elevations thus arising on the cornea act like small collecting lenses in the sunshine and in the illuminated part on the retina give an almost clear and encircled image of the light source in the middle of a shadowy space, which corresponds to the extent of the small inequality. In an umbrella with a triangular opening (as easily pricked with a compass point) each drop appears with a triangular central figure of light in the same position as the opening, and there are also two or three small, very close openings of each Drops are repeated in an upright position, which results in the wrong position of the images lying on the retina. but downwards stems from a really upwards movement. The movement results from the movement which the eyelid, which is drawn upwards, causes under the essential influence of the viscositil of the mucous membrane. Drop-like phenomena are sensible in the upper part of the light field in FIG. The very mobile, liquid coating of the front surface of the eyeball, which is woven anew with each stroke of the eyelid, and from the secretions of the conjunctiva, of the Meibomian glands in the SO, which are very different in their degree of viscosity

p37 Lieder, the ciliary hair follicles and the tear glands, offer great differences, depending on the various physiological and pathological conditions of the eye, and so entoptic observation of this moistening mechanism was permitted can be used by both the physiologist and the doctor in the event of further follow-up. If the eye was closed for a while before the observation and pressed or rubbed from the front with the fingers, then the entire field of confusion shows, apart from the more rapidly changing phenomena observed up to now, a fairly uniformly distributed veil of larger and larger indefinitely delimited, dark spots and lines, which, like a tapestry pattern, present sometimes a tiger, sometimes a net-like, sometimes a meandering or wavy appearance. During the movements of the axis of the eye, the parts of this coarse-meshed tissue keep their opposite position and shift noticeably in the circle of confusion, or in the thread network imagined therein, in a direction opposite to the movements of the point of vision External pressure 3. The anterior surface of the cornea that has become. lung. Unevenness, ripples, wrinkles, or folds caused on the convex surface of the cornea, which are manifested entoptically by substantial modifications of the refraction occurring at this interface. This abnormal condition, artificially created on the cornea, is not only differently pronounced in the entoptic spectrum, depending on the duration of the previous pressure, but only goes away after a shorter or longer period of time (sometimes within a quarter of an hour, in other cases not until several hours) gradually passed. Different directions and distributions of the pressure appear to be different types of folds of the cornea in addition to the SO

p38 thin overlying conjuncliva, and according to this various drawings and tissue patterns in the entop-. table appearance. FIGS. 14 and 15 show, for example, two types of corneal ripples that have been observed on various occasions in my left eye peculiar differences in the drawing of whole parts of the tissue become discernible. The stronger flexural halls indicate greater suppleness in the affected areas of the corneal surface. Fig. 16 gives an example taken from my right eye. Two disc-shaped parts of the cornea appear in the circle of dispersion, above a larger, more clearly delimited, and below a smaller, more difficult to discern, to which a greater rigidity than the adjoining parts must be ascribed. It hardly needs to be recalled here that these points on the cornea have the opposite effect. This phenomenon, which Young has already mentioned, must be drawn to attention here, in order to avoid confusion of this temporary phenomenon in the case of alternate entoptic observations on both eyes Condition of the eye with an essential or constant error in which the incapacitated. The ability to warn a skilled observer is easily lost if, when he closes the idle eye, he exerts pressure on it with his fingers, and then proceeds to an experiment with that eye. In such cases, you can avoid the annoying pressure on the passive eye by holding it closed with the flat Iland instead of with your fingers.

In addition to the three types listed, more changeable).

Note 1) A course of lectures on Natural Philosophy and the Mechanical Arts, vol. II. P. 581. SU

p39 of optical phenomena in the circle of confusion, which, it seems, are perceived by almost all eyes, only with gradual differences, there are now several others, which only in a few eyes are due to special peculiarities or pathological ones Conditions occur. A more precise analysis, for which the method of observation discussed here provides an expedient means, has not been possible at the moment, because in my eyes such phenomena are almost entirely absent and the facts taken from other eyes are still too inadequate, and is therefore reserved for future investigations by the ropes of skilled observers, whose eyes have the necessary peculiarities. In addition, there are cases to be taken into account in which in the aqueous moisture there are filamentous, membrane-shaped or otherwise shaped organic structures, rudiments, etc. Wall sticking, swimming around, and by mechanical effects, such as turning the eye, shaking the head, accidentally step into the effective beam cylinder and thus the difference in its refractive ratio from that of the surrounding liquid, or else through its peculiar coloration and opacity, becomes entoptically perceptible. Such bodies floating in the watery moisture will then cause scotomas which differ from those described above, if they are diaphanous

Note 1) , like those of Wilh. Sömmerring (Isis 1830, p. 717) and Logan (case of Animalcule in the Eye of a child 1833), of inland animals in the anterior chamber, which are certainly very rare, would also belong here. In the remaining few cases of animals in the refractive means of the human eye, which v. Nordmann (Micrographic Contributions to the Naturgoschichto of Invertebrate Thiero, Booklet I. P. 7 and Hef II. P. IX), the entozoa were found inside of extended cataract lenses.

p40   normal eye floaters can be distinguished both by their shape and mobility, as well as by a high degree of indistinctness in normal vision in non-homocentric light. In the following we shall find occasion to make occasional remarks about some phenomena that belong to this class.

13.

We now consider the persistent entoptic phenomena in the field of dispersion of the almost parallel homocentric light.

Because of the frequency and diversity of the variable phenomena that can be perceived in each eye, the discovery of persistent internal objects of the eye first of all requires a prolonged and frequently repeated observation, because only then will it be possible to identify the movable and changeable of the permanent appropriate to distinguish and separate. After having made himself familiar with the constant entoptic silhouette peculiar to his eye only through sufficient repetition of the experiment, he will soon be able, taking into account the remarks made at the end of Article 10, the position of the objects seen or of individual parts to determine the same in the imaginary crosshairs of the circle of confusion and thus to determine topographically, as it were. then only depend on the practice of the sense of proportion and the skill in tracing whether he succeeds in realistically reproducing what he has seen; and under otherwise the same circumstances, this becomes much easier here, where the original can be presented to oneself again at will at will, as a representation of changeable and transitory phenomena; just as much less art is required to trace dead objects under the microscope.

p41   is different than for the correct apprehension and graphical fixation of movable or living objects. A means of relief that can be used with objectively seen lines or bodies will almost completely fail here. If a very small convex mirror (mentioned several times) is used to produce the light source, the constant entoptic figures would be removed a drawing, as can be made by means of the camera lucida, by mechanically tracing the outlines projected onto the background or the paper through the lines of sight, would not, as shown in Art. 10, have the whole circle of dispersion mobility dependent on the movement of the optical axis. If the displacements not only of all points of the circle of confusion, but also of all constant objects perceptible in it were in the same relation to the movements of the point of vision, then, theoretically taken, a drawing similar to what was seen would be reduced to a smaller extent 1) in the above-mentioned manner can come about in which every point, seen directly, would coincide with the point shown, the practical execution of which, however, remains very difficult even for the trained draftsman because of the non-coincidence of all the parts lying laterally from the point of vision. But the picture would have to become completely dissimilar as soon as, what actually occurs, that relation does not agree for all objects with that of the circle of dispersion. In some cases, however, this principle will be used successfully by bringing a suitably adjusted scale to the background for the purpose of measuring instead of a paper surface for drawing.

Note 1') For the numerical values used in the note to Art. 10 in the (lincaren) scale of 0.61.

p42 .

14.

Are opaque bodies or transparent bodies whose refractive index differs from that of the neighboring one in certain places in the eye on the path through which the rays belonging to a system almost parallel homocentric light pass If the medium is different, such bodies must be perceptible in the eye in a known manner through cast shadows or through partial deflections of the rays. If the light source is in the front focal point, then the sight point (with a concentric diaphragm opening) will lie in the middle of the circle of confusion, and all inner rays will go parallel with the axis. Position of the axis to the light source the first in order to distinguish it from a position we first call this other, the second, into which the axis is displaced by moving the eyeball around the fixed point of rotation when we move the point of view to a moving agreed to relocate to the center of the circle of confusion. Cross section of the eye QAS the crest boundary surface, II the pupil, RLT the retina and AL the axis in front. In the first position of the axis to the light source, QR and ST are the boundary rays of the inner light parallel to the axis. If we now add three places M, M ', M "on the axis, in which there are shadow-casting bodies, the first in the plane of the diaphragm, the second in front of it, the drille behind it, then in this first position of the id 17 the three opaque bodies cast only a shadow in the mill L of the illuminated field RT lying on the retina and appear entoptically as a single object in the mill of the circle of confusion Eye, which may be brought about, for example, by a downward movement of the point of vision, are larger and larger, the three are now further for

p43 body M, M ', M' create three different shadow areas 1,, I on the retina, and thus appear separately, while at de A look at the figure (under If the wrong position of the retinal images is taken into account, it is easy to see that in both positions the body M appears in the center of the circle of confusion, while the other two are displaced in the circle of confusion on the transition from the first to the second position, M 'upwards and M' 'downwards. These changes of location would be the opposite with an upward movement of the sighting point. Similar conclusions apply to objects which are not in the axis. It follows from this that the persistent inland objects Depending on their distance from the plane of the diaphragm, changes in their apparent position below themselves and towards the circle of confusion coincide through the first position of the point of vision, namely that all h Objects in movement under the pupil show one in the same direction as the movements of the visual point, but all in front of the pupil show an opposite movement in the circle of confusion, and that only objects in the plane of the pupil are free from this influence . The relative entoptic parallax of an entoptically perceivable object in the dispersion circle, depending on the movements of the sight point, can be expressed as follows: the relative we call this entoptic entoptic parallax is zero for objects in the plane of the pupil , positive for objects behind and negative for objects in front of the pupillary plane. Their size!) is

Note 1 na-) The amount of this parallax can easily be found from the expression given in the note to Article 10 for the measure of the absolute parallattic movement of the entire circle of confusion. let e be the distance of an entoptically perceptible object from the plane of the pupil, positive if the object lies behind this plane,

P44 is proportional to the movement of the sighting point and the distance of the object from the plane of the diaphragm. For objects in the cornea, about 3 m in front of the pupillary. lying on the same level, for objects on the back of the crystal lens, about 5 mm behind the pupil, it is close to the movement of the point of vision. In the first case the movements are in opposite directions, in the second they are in the same direction. Objects on the anterior lens capsule - membrane, the distance of which from the plane of the pupil is scarcely a millimeter - this parallax is so small that it will escape the most trained eye. Such objects, especially those located in the anterior capsular membrane, will therefore take the place of a thread network in the eyes in which they are found, and the observation of the relative displacements of others, especially in the cornea or in the fore,

Note from p43 cont) to the same extent how the quantities a, b, c, d are measured, so finds (a-6) c + ad which can also be written from the expressions bc 1– 4 (CT, by substituting a -e instead of a the bc For the absolute parallax of the object = 1– ae) (c + d) pun, therefore, the excess of this measure over that of the pupillary edge with respect to e (c + d) smaller than the relative in the circle of confusion. Consequently the ratio of the movement of the object to that of the point of sight, both changes of location, is measured relative to the thread network considered in the circle of confusion or the measure of the relative entoptic parallax - the sign agrees with that of e. For the a. a. O. the numerical value chosen for the distance of the diaphragm from the retina, this measure (under the assumptions on which it is based and in a similar approximation) is equal to the ratio of the distance e from the internal object, expressed in millimeters, to the number 20, and the parallax itself is equal the relative angular movement of the point of vision in the circle of confusion multiplied by this ratio.

p45 crystalline lens facilitate more persistent internal objects lying backwards. Acceptable objects which have fixed places in the vitreous, at certain points of the diaphragm, their (positive) parallax would be very noticeable, and be contained between the fourth part and the whole amount of the visual point movements. of this kind, apart from their peculiar movement, show the usual floaters discussed in Art. 12, which are as a rule at a very short distance from the retina. They mostly accompany the point of vision in its movements at almost exactly the same pace, so that few of them, who happen to be seen in one eye, enter the macula lutea through direct vision, but most of them only indirectly let percipate. While the spectrum of the persistent internal objects seen in the circle of dispersion shows the distribution in the dimensions perpendicular to the axis unmistakably, in the relative entoptic parallax we have a diagnostic aid for the approximate determination of the distribution in the dimension of the axis itself Diagnosis will, of course, be much more difficult than the view discussed in Art. 13 because of the sharpness of vision in the vicinity of the point of vision, which decreases rapidly with increasing elongation, and because of the uncertainty of the visual dimension to be extended to a larger area on the axis. and therefore generally remain of limited applicability. but it is likely that it can be granted some practical significance in addition to its theoretical value in individual favorable cases, especially where it should permit a connection with other anatomical or pathological facts. In the following, this relative parallax will find essential consideration even more often.

Figures 18 to 43 now show a series of persistent entoplic Spectra by different people 1). Even at a cursory glance, the greatness falls.

Note 1) I have had the figures follow one another according to the alphabetical order of the observer, and that of every artificial classification by which the eyes of an individual are separated from one another, and which are so small in number observations at the moment should still seem quite worthless, preferred. The names of the observers (together with details of the place of birth) are: Fig. 18 Hr. Professor Bergmann (Göttingen) Dr. Casselmann (Rinteln) Architect Cavallari (Palermo) Dr. Claudius (Lübeck) Lieutenant Dammers (Eimbeck) C. Guthe (Andreasberg) Stud. G. Guthe (Andreasberg) Dr. Krämer (Göttingen) Lier (Göttingen) Prof. Listing (Frankfurt a. M.) Engraver Loedel (Hameln) Dr. Merklein (Nuremberg) "Inspector Meyerstein (Eimbeck) Abbé Moigno (Paris) City Syndicus Oesterley (Göllingen) Stud. Ringelmann (Osnabrück) Professor Ruete (Scharmbeck) Dr. Sartorius v. Waltershausen (Göttingen) Hofrath v. Siebold (Würzburg). Dr. Ştern (Frankfurt a. M.) Stud. Uhlhorn (Osnabrück) Professor Ulrich (Göttingen) Assessor Unger (Hanover) Professor J. Vogel (Wunsiedel) Stud. E. Weber (Badbergen) Stud. H. Weber (Thedinghausen) 61 20 22 46 23 25 26 11 27 32 46 33 44 11 34 35 38 44 42 43 The illustration of the left eye in Fig. 21 is complete because it has been completely blind for 16 years as a result of a lens cataract. Observers of Figures 23 and 24 are brothers. Thieves-

P47 diversity and uniqueness of this spectrum, although a certain resemblance between the two eyes of an observer, the spectrum of the left and right eye of an observer are represented and distinguished by the letters L and R. From a much larger number of observations, only those are included which have been verified more often in shorter or longer periods, so that the intended elimination of the temporary entoptic phenomena discussed in Article 12, with which some of the persistent ones show great resemblance at first sight, no doubt prevails. For some this period is more than a year, for those relating to my eyes (Fig. 27) it is about 2 years. Continued observation of a certain eye for a long time will be able to provide information about the possible gradual changes in the persistent internal objects, which are only noticeable after longer intervals, as this is in fact already unmistakable in my right eye. In every figure one can achieve changes, the course of which can be observed in detail in some pathological occurrences, obviously not only of general physiological interest, but also of particular pathognostic interest. Incidentally, it should be mentioned here that the observations communicated relate only to healthy eyes or to those eyes whose function in ordinary vision (partly with, partly without glasses) is not impaired by any prominent ailments.

In addition to a net-like or pile-like covering of the entire field of diffusion with mostly very indistinct but fine meshes, which was found in all eyes subjected to the examination, in 50 of our 51 Spectra there are still special internal objects of a certain number and configuration, and only in In one (Fig. 42 L) we find the circle of confusion completely empty, that is, the breaking ones

p48 . Means (at least in the area of the transmitted parallel homocentric light) completely free of persistent internal objects. One may conclude from this that in most eyes there are by far such places in the refractive media which disturb the regular passage of a lesser or greater quantity of rays of light. More numerous observations in the future will show us the ratio of exceptions (perhaps barely 3 per cent). The disadvantage which arises in healthy eyes from this peculiarity for the ordinary visual function, where the regularly running rays of light combine in completely or nearly sharp images on the retina, is just as little noticeable as when small partial opacities appear in the objective glass of a telescope or air bubbles. But as soon as the amount of light absorbed or perturbed in this way comes into a considerable proportion to that of the intact, a noticeable impairment will inevitably arise from it. If here, as is also not unusual in other cases, there is only a quantitative difference, that is, no sharp boundary, between normal and abnormal straight lines in the transitional cases, but creation. and in the case of illnesses that are gradually expanding into space, the entoptic observation of the eye employed here does not seem to be able to provide unwelcome diagnostic services.

16.

The pile-like coating, which is probably perceptible to every eye in the circle of dispersion, is not the same in all eyes because of its special nature. Its obscurity depends, in addition to the degree of transparency of all the media, on the light intensity of the luminous background and on the relationship between the cladding and the

p49 pupil from measured fine opening of the screen to clothe the circle of confusion. Under normal circumstances it is about 1600 times less than that of the freely viewed background!). This brightness is uniform in the entire field of confusion, as in my left eye and many others, in some eyes is uneven, as in my right eye, or as in Fig. 28 R, Fig. 40 L and R, Fig. 41 R. shape seems to be the result of the non-uniform transparency in the refractive media, namely the cornea (my right eye) and the crystalline lens together with its two capsular membranes. The meshes and parcels of the pile-like network that appear but indistinctly delimited and often confused are mostly of great delicacy (especially when the light of the background is very subdued and the interference is removed as much as possible) and in this respect essentially different from those found in the coarse-patterned network Art. 12 is used to perceive the spectrum created by the folds of the cornea (Figs. 14, 15, 16). Incidentally, this network offers various differences, both these inequalities, the individual mosaic-like in terms of brightness, similarity and regularity, and in terms of the clarity, size, shape and positioning of the elementary parts, as the figures (especially Fig. 20, 22, 26, 27, 28, 29, 40, 41) adequately explain. This reticulate veil appears to be a result of small aberrations which the light that passes through suffers due to very small but numerous irregularities in the curvature of the various interfaces between the transparent media of the eye. This effect is therefore the

Note 1') The brightness of the circle of confusion can be imitated with the naked eye if one looks at the background through 16 to 18-fold black crepe (black ribbon).

p50 , which we can easily perceive in the sunlight falling through an ordinary, unpolished pane of glass when we catch it on a white surface. The negative relative parallax, which can be seen in many of the more noticeable light cells in the circle of confusion of my two eyes, and especially the right one, indicates the cornea as the seat of many of these entoptically visible and closely related to the histological nature of the interfaces standing irregularities. At the same time 9. it seems to be particularly these distractions affecting the first refraction, which cause a striking irregularity in the distribution of the inner convergent light when the distance of the light source from the eye is gradually increased to the distance of the listener, and so on cause the well-known (each eye in a different way) anomaly of the multiple images in uniocular vision on this side or on the other side of the horopter. Where the meshes look stretched and streaky and show a radial arrangement, as in FIGS. 26 L and R, 40 L and R, 22 L, 28 L, the cause seems to have its seat essentially in the anterior lens capsule. As for the deviations of the limitation of the field of confusion from the circular shape mentioned in Article 9, which are only of subordinate interest in healthy eyes, they are included in some figures for example and are faithfully reproduced by the observers. This is especially the case in FIGS. 20, 25, 27, 28, 39, 40. In FIG. 39 L they are particularly striking.

17.

The persistent interior objects are represented in very different drawings on the pile-like background of the circle of confusion. The high degree of un-

p51 The variability that these objeoles show entoptically seems incompatible with the assumption that they are in the liquid media of the eye. as the cornea or the crystalline lens and its capsule, we shall therefore have to consider them as belonging. The phenomena originating from the cornea can be recognized entoptically by a noticeable negative parallax (Art. 14). those who suffer no discernible displacements as a result of the movements of the point of view, or whose relative parallax is imperceptible, must either be added to the anterior capsule membrane or the anterior side of the crystalline lens. objects lying behind, i.e. inside the lens or on the posterior capsule, which can be recognized as such by a conspicuous positive parallax, do not appear in the few experiences available here, but they become like that Occurrence of congenital posterior capsule - makes cataracts likely to be observed entoptically from time to time in the future. skinobjecte is very small in our observations. Most of the persistent objects appear to belong to the anterior part of the number of horns of the system of the crystal lens.

18.

We shall first consider the few examples of corneal objects which the Spectra given here have revealed as such. In Fig. 24L we see a large round spot. Its basic color is brown-yellow, the drawings it contains are black-brown, the border is light and, with the exception of a small interruption in the upper left, sharply delimited inside and out. It shows a clear negative parallax. His position in the figure is that which

p52 is due to him for the visor point shifted in his center. This corneal spot, about 1.4 millimeters in size. and can easily be noticed from the outside (objective) in the eye, is the result of an inflammation of the cornea from which the eye suffered a year before the entoptic observation.

Fig. 27 R. The spectrum of my right eye shows two almost circularly delimited parcels of the clear Flores, a larger one above, a smaller one below, and also a very indistinct clear arc-shaped strip that penetrates almost the middle of the upper parcel, but is still much indistinct within appears more obvious than on the outside, and finally a smaller one, standing to the right of the lower plot, very indistinct. These phenomena reveal themselves as belonging to the cornea through a negative entoptic parallax. Your position shown in the drawing applies to the sighting point located in the center of the circle of confusion. The two parcels delimit each other much more clearly when the cornea is pressed from the outside for a while, as already mentioned in Article 12 This slightly limited darkening. essence, discussed and shown in FIG. Unities in the composition of the horn structures are so insignificant that they are perhaps no other than entoptically perceptible. They disturb the normal visual function only to a very small extent, and the fact that this eye is somewhat inferior to the left in terms of ability to see (not in sharpness) may be due more to the habit of mostly using the left in uniocular vision than of these small irregularities in the structure of the cornea, it has not shown any noticeable changes for three and a half years. is likely innate. The right eye shows no trace of such a phenomenon. In Fig. 28L a black line extends from -un

p53 of uniform strength, comparable to a crack in a broken pane of glass, from bottom right to top left almost right through the middle of the field of confusion. The position in the drawing corresponds to the case where the center of the circle of confusion is seen directly. If the light spot located at the top left is directed, the black stripe assumes the position of a diameter, a sign that this fine dark line lies in the cornea. This persistent corneal object is so delicate, as can easily be seen from the entopical spectrum, that it cannot be seen from the outside.

But if the axis is on the In Fig. 39L there is an elongated dark spot at the top of the spectrum. The drawing shows him in the place which he directly occupies. At the point of vision at the lower edge of the light field, the spot gradually moves to the upper edge and is partly hidden behind the peninsular protrusion of the iris located here, as is indicated in Fig. 39L '. This small spot in the cornea appears to be due to the passage of a temporary inflammation found on the eye 18 years ago. may not only be the strong sinuosities of the pupillary rim, but also a peculiar, mutable optical phenomenon of the same origin in this eye. At various points in the field of vision a shadowy, indistinct scotoma appears during normal vision, which once, when it happened to be in front of the pupil, could be observed more precisely entoptically in the parallel homocentric light and in shape (Fig. 39 L ' ") of an animal-like body appeared. This internal object, the rudiment of a structure resisting resorption, floats freely around in the watery wedge of moisture without attachment. It was (without the filamentous appendages) about 1 millimeter in length and as much in breadth .

On this occasion I might like one more with that one

p54 mentioned Scotom can be cited as a kind of related phenomenon. It can be regarded as an example of the rarer de-optical phenomena of a variable nature, which we thought about at the end of Article 12. Appearance, although not really one of the persistent ones, could be included in the spectrum, insofar as the object, even if mobile in the form and position of its constituent parts, still occupies a certain part of the field of dispersion. the part of the field lying below and to the left is a convolute of spider-like and undulating lineaments which change their mutual position noticeably when the eye moves Maintain the direction from bottom right to top left. and from the changeable form it may be concluded that in the anterior chamber there is a fluttering, but partly attached, filamentous or membranous, very transparent structure of watery moisture, the transparency of which makes any other than entoptic perception (by means of a fine opening) impossible, which, however, seems to be related to a very light, whitish sediment in the anterior chamber, noticeable from outside, near the edge of the cornea. From the recognizable negative parallax. By the way, ordinary vision is hardly at all impaired by this. The representation in the figure relating to this part of the spectrum can only make the appearance more or less sensible according to its habitus, while the other parts, like those in other eyes, are precisely traced. Other experiences give rise to the supposition that it is precisely phenomena of this or a similar kind that constitute the chief difficulty in fixing and tracing the spectra of their eyes for some persons. Multiple

p55

19.

While the cornea is the scene of very frequent variable phenomena, as has been demonstrated in the 12 article in more detail, it comparatively seldom forms the seat of constant objects in the entoptic spectrum. On the other hand, the components of the lens apparatus, and especially those in front, appear as the assembly point by far of the greatest number of persistent inland objects. Namely, the numerous objects of our Spectra that are still to be looked at show either no noticeable or only a very slight positive parallax, and we can therefore only point out their position on the anterior lens capsule or on the foremost layers of the crystalline lens attention has already been drawn to this earlier (Art.

17). For the Wabl, however, between the capsule and the lens, the relative entoptic parallax alone does not provide a reliable criterion; It therefore remains undecided as long as no other anatomical and pathological features make a reliable diagnosis possible Showing interest, and it will, are only more numerous observations, especially small ones. also pathological cases, obtained and connected with anatomical facts, give way to others, which are based on more essential differences. Among the objects under consideration here we find 1. pearl spots, 2. dark spots, 3. light stripes, 4. dark lines. The pearl spots are round discs or round spots that merge into angular spots, light inside, usually with SO

p56 sharp dark edges. The round, identical little air bubbles, the angular, small, transparent pieces of crystal, viewed in a bright liquid under the microscope with light shining through; the larger, rounded ones often resemble drops of oil; those on water have a very bright core of light which runs with more or less distinct colors into the dark edge. Some show a light border or halo, others do not. In Fig. 30R the contour runs from the inside outwards from the white core through yellow, your clothes float. pale and light blue in the surrounding pile. is very different, but even the smallest appear as a rule larger than the discs described in Art. the Muscae volitantes are placed. the. Their distribution is usually very irregular in the circle of dispersion, and although in eyes, where their number is large, there are sometimes mebrere compressed to the touch, they show no tendency to be arranged in rows or strings of pearls. See Figs. 29, 33, 35, 36, 40, 41, 43. They occur in the majority of the eyes, either alone, as in Fig. 30, or in association with the other species, as in most of our eyes right eye gives an example of Neubil figures. formation of such internal bodies. The small round pearl just below the three-sacred dark spot (Fig. 27 R) was created only recently (in July 1845). experience will be made more often in the future. A small positive parallax has been perceived in the eye in Fig. 18R at the very bottom porl spot, which is perhaps similar to the dendritic light streak in the vicinity and differs in the same direction as the point of vision

The pearl spots are not distinguished by the lack of a bright core, SU

p57 but also through greater diversity in shape. Their inside is differently dark, from light gray to black. Their shape is round or rounded (Fig. 18 R, 23, 28, 31, 32, 36 R, 37, 39 L, 40 L, 43 R) or angular, sinuous and provided with lobes or wing-like attachments (19, 31 L, 36 L, 42 R). Sometimes they form groups in which the composition seems to be less random than in the case of pearl spots, and then appear as three- or more-part spots or systems (19, 26, 36 R, 37 L). In rarer cases they become amorphous (22, 39 R). They are, especially the roundish ones, more often provided with a light border than the pearl spots on the edge (18 R, 23 L, 25, 26, 27, 28, 31, 32, 37). the simple spots seem to vary somewhat less, the size than that of the pearl spots. The internal bodies or the darkened areas can be 0.04 to 0.30 millimeters. to be appreciated. Their frequency, too, seems to be somewhat lower than in the previous species. They do not only occur in the spectrum, as in Fig. 25 R and L, but also together with the other kinds of objects, and often appear both individually and in groups , added or incorporated into the strip of light (18 R, 26, 28, 31, 32, 36 R, 37, 40), sometimes also linked to the pearl spots (22 L, 29, 42 R). The tri-sacred dark spots in both of my eyes show a small, but surely recognizable, positive parallax, which is particularly evident in the left eye through the clear moving away from the near-lying (newly landed) pearl when the point of sight of the Spots from horizontally on the left towards the border of the field. The pearlescent spots have very little or no parallaxes, even with regard to the position of these three-part dark spots, in the center of the circle of confusion. points,

the light stripes usually form a kind of dendritic p58 slim figure with a more or less distinct center. than the pile, against which they are sometimes demarcated (Fig. 20, 26, 28 R, 40 R), but sometimes also in sharp, dark and in places broad outlines (18, 21 R, 32, 37). Their course is mostly curvilinear, vein-shaped, in some cases ring-shaped or wall-shaped, enclosing the center (21 R, 31). The branches are of very different lengths and can extend over the greater part of the field of diffusion, as in Fig. 18. They are, like many pearl spots, of a light width of the dark-outlined stripes, alternating between 0.08 and 0.25 Millim. The central part of the figure of the streak of light is usually near the center of the circle of dispersion, more seldom far from it (21 R, 28 R). A parallax has not yet been observed. The light streaks often appear with pearls and dark spots at the same time in the spectrum, but not with the rarer dark lines!). and without a light-streak figure, Spectra seem to be of almost the same frequency in our observations.

Finally, the dark lines differ from the light stripes not only in their dark appearance, but also in their smaller width, less clarity and more straight lines. dial arrangement and, from the extent of the circle of confusion, seem to aim towards a common center which some reach but others do not, as they go out on the way, as it were. Cf. Fig. 23, 24, 27, 35, 38 L. Their zabl is sharply different and sometimes much larger than the number of branches in the light streak figures, and they then go, like the figure 35 compared to Fig. 40, 41, 22 L, 26 and 20 shows gradually in a radial mesh they mostly show a ra

Note 1-) The spectrum Fig. 28 L is no exception here, since the dark line, as in before. Art. Shown, which belongs to the cornea. S0

P59 The dark lines appear with pearl spots and dark spots at the same time, whether also with des Flores over. Stripe figures, of which, as noted earlier, our Spectra do not show an example, will only have to emerge in the future from numerous experiences.

20

As to the anatomical and physiological nature of the internal bodies which the various kinds of persistent entoptic phenomena described in the previous article cause, no definite explanation can yet be given, indeed no well-founded assumption can be made. If we also know in general that these points of the refractive means which impair the path of the rays of light are to be found at a short distance from the pupil in the anterior part of the lens or its anterior capsular covering, we are still a long way from enumerating the individual Ways of being able to attach peculiar seats and analomic meanings. That the light-streak figure is the image of a transparent navel-shaped structure with branch-like or bulge-like branches in the anterior capsular membrane, originating from the separation of this part of the capsule from the inside of the cornea in the fetal country!), must first be confirmed or refuted in finer anatomical observations to be made for this purpose. Of the three other species, the light and dark spots and the dark lines, it can hardly be assumed that they individually only find the cape. The view of this organ. sel or belong only to the lens. Rather, it seems singularly, partly from the relative entoptic parallax indices to point out that visible visuals removed from the Morgagni moisture '

Note) Cf. Huschke in Mockel's archive 1832. p. 17.

p60 and condensirle (also anatomically observed in it) attach mucous bodies to both the anterior capsule and the anterior surface of the lens and then cause the appearance of pearl

spots; Furthermore, through cataract-like darkening of both organs, the capsule and the lens, the dark spots can arise, which are then often closely connected on the one hand with the imaginary scarring in the capsule membrane, on the other hand with the organic structure of the first Like lenticular layers; that, finally, the dark lines can be the entoptic expression of the directions of splits or secretions, which in the capsule are anatomically related to the nature of the closure and the scarring when it is detached from the cornea, in the lens with its sector-shaped components. Attention may also be drawn here to the possible connection between the membrane of the posterior capsule, which was found to be consistently objectless in our observations, and the rarity of posterior capsular cataracts, as well as to the histological and analomic difference between the anterior and posterior capsule.
The comparison of our Spectra with the darkening forms that occur only to a greater extent and are therefore objectively perceptible from the outside, as they occur in the various types of capsular and lenticular cataracts, is suitable, not just those already mentioned above (Art. 15) to explain the gradual transition between normal and pathological states of the organ of vision, but also to provide useful data when studying the physiological nature of the entopical internal bodies. In the representations of some cataracts appended to our entoptic figures') there are shown in part and

Note) these representations, which I have given my SO

p61 These images, which, apart from the higher degree of opacity, I have given the pleasing healing of my 19 striking similarities with the persistent entoptic appearances of healthy eyes. The connection, however, of the external (objective) diagnosis with the type of de-optical observation of the cataractous darkenings and the rest of the course in cataract eyes, described here, should perhaps in future be of interest in two respects, both for the physiology and for the pathology of the sense of sight . closer examination and judgment, however, remains entirely up to the ophthalmologist.

Note continued from p60 The Freundes, thanks to Professor Ruele, represent the following forms of cataracts: Fig. 44. Capsule - Staar. 45. soft capsule -lenses - cataract. 46. Capsular-lens cataract, very rapidly, probably due to inflammation. 14 47. hard lens hair. 48. Congenital lenticular cataract. 49. Posterior capsular cataract. Cf. also v. Ammon's clinical presentations of the diseases and malformations of the human eye. Berlin 1838. Part I. Tab. IX, X