Sight and the visual organ / by A. von Graefe.

SIGHT

AND

THE VISUAL ORGAN

BY

A. von Græfe.

WITH FIVE WOODCUTS.

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Be the idea what it may, that we form to ourselves of the mysterious tie that links our *perception to the life of the soul*, so much is undoubted, that the material supplied by the impressions of the senses constitutes the basis on which the soul unfolds; farther, that they furnish the nutriment on which our thoughts and conceptions live and grow, and that through them alone is preserved the connection between the invisible "I" and the external world, the soil in which all conscious intellectual activity strikes root.

The child does not come into the world *fitted out* with elementary notions, as the idealists have taught, but endowed with the capacity for *acquiring* those ideas, as first promise of the inborn power of the soul, as soon as those impressions, coming to it through the senses, furnish the "intellectual fuel" for the first psychical processes. And, obviously for this embryo stage of mental life, the association of the senses of seeing and feeling, is of peculiar importance, — a conclusion which is now confirmed by experiences collected from the ever-widening circles of knowledge. The richer the world of sensuous impressions is, and the more manifold the relations of sense to sense are, so all the more numerous and varied do such inductions start up around us, the testing of which is infinitely facilitated by the natural development and thorough exercise of the powers of the mind. By means of a process of collecting and comparing, compound ideas are evolved out of

simple ones, and the normal, logically organised mental life, attains an ever higher development, while by the inexhaustible activity of the senses, it receives a never-failing supply of fresh material for the perfecting of its psychical structure.

But though the mental life be thus developed, still the waking consciousness of each moment is only preserved by the never-ceasing action of the *senses*. Should they relax, the ground gained by the aggregate experience of the mind, and standing on which the individual takes his place in the order of things,— would waver and become uncertain, and we ourselves should gradually sink into a more unconscious state. That this should indeed take place from time to time, is a condition and law of nature, to disregard which would be to weaken both the vigour of the senses themselves, and the mainspring of our faculty of perception. *Sleep*, to which I here allude, is generally sought for by removing from us as far as may be, everything that stimulates the senses. When we succeed in bringing about an adequate diminution of the sensuous irritation, already lessened by the fatigues of the day, the result is the suspension of conscious physical activity. If we cannot fall asleep, the reason is to be sought for in the non-fulfilment of that condition; we have, let me say, not succeeded in relaxing the senses so far, as not to be disturbed by some straggling ray of light, or by some slight noise, or even by the position of our own body.

The action of the senses during sleep being merely lessened, not nullified, consciousness is hence not entirely obliterated, but simply reduced to a lower grade. In dreams we preserve our own peculiar personal sensations, and also to a certain extent, consciousness of our connection with that which surrounds us. When refreshed by a season of slumber and

the senses have recovered their elasticity, they likewise recover their power of receiving clearer and sharper impressions. The slumber first begins to grow lighter, consciousness arouses to a higher, though still only to a rudimentary degree of existence; dreams chase each other less rapidly through the brain, and in their nature and structure depart less from the rule of waking conscious activity. Next follows the *awaking* itself, when, as in the primary psychical processes of the child, the simultaneousness of the impressions of the different senses, restores the mind to its powers.

But in certain other states of insensibility, it is still easier to prove this maintaining of consciousness by the action of the senses, than in that of sleep. Ether, chloroform and such narcotics when inhaled, first relax the vigour of the nerves of feeling, which manifestation has been put to abundant utilitarian purposes by the crafty practioners on human credulity. But the narcotic medium likewise extends its influence to the other senses in perfectly normal succession. There is nothing to prevent our graduating the state of insensibility in ourselves, so as to make the stages in which one after the other, we are deprived of our five senses, follow with the slowness necessary for observation. Arrived at this point, it is for us to strain our will to the utmost to keep awake within us the idea of the situation, as also any thoughts as may serve to animate our consciousness, and this we may succeed in doing, even with a greatly diminuished irritability of the skin, and an increasing decline of the other senses. But when the final impression of hearing, that last strong hold of the objective action of the senses is lost, then, and not till then, do dreams hover around our soul; and the lost consciousness cannot revive but with the re-instatement of the senses in their wonted state of activity.

In the ethical development of the life of the soul, the part which the senses play, is most complicated and not to be explained in a few words. So much however, I may be permitted to say that, through the medium of the senses, a deep internal harmony is maintained between the perceptions and the ethical ideas; and sentient man sees and acknowledges in the development and utilizing of this internal harmony, the chief source of his culture. To gaze on the grand scenes of nature, to listen to sublime music, and to indulge in other ennobling impressions of the senses, awakes in us undeniable, though still vague ethical conceptions, whose office it is to aid us in attaining the objects and aims of an inner mental life; and in preserving a balance in the human soul, which is unceasingly subject to the sway of distempered causes.

According to this, it seems then, that the senses are indeed the gates to the mind, through which aliment passes for the sustenance of the in-dwelling powers; but equally, they are the portals, through which science must endeavour to penetrate into the visions and conceptions of the mental world. This has often been attempted, it is true, though in another manner, as for instance, by laying down postulates on the nature of the soul. But here we must admit, that since the beginning of the world, this manner of committing our thoughts to the guidance of metaphysical hypotheses, has never increased our knowledge even by a hair's breadth. And further, that in taking a survey of such labours, we can convince ourselves, that in this field, properly inaccessible to the human understanding, it does little more than move in a circle; or carried away by the notion of imaginary greatness, it loses itself in devious paths.

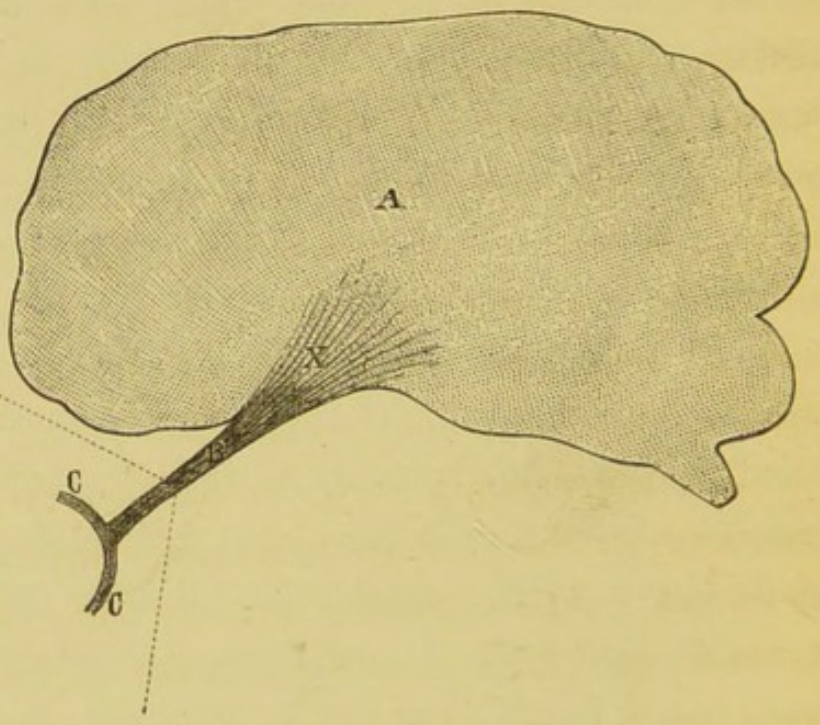
Fortunately, the majority of thinkers have now struck

into other paths more promising of results, and in which, though conscious of restriction, still the human understanding labours with honest observation and analysis. In the same degree as essential progress has been made in the knowledge of the human body, since men have ceased to indulge in subtle speculation, and enquiry into the nature of the principle of life, and turned with an undivided and stern spirit of enquiry into the laws of organic appearances; and since men, unheedful of the essence of the soul, have applied themselves to trace with care the psychical manifestations of the elementary processes of perception up into the world of conceptions and ideas, and to do the utmost in their power to discover the laws which there govern, there has arisn another science, forcing itself more and more on our notice as it daily proves itself to be possessed of an inherent vitality. I refer to the science of *psychology*.

Such being the nature of the change in our scientific starting-point, the operations of the perceptions which formerly busied thinkers not specially occupying themselves with natural sciences, except in their most general features, could not but acquire a wider significance. Resting therefore on their increased significance, I now venture to bring before you the structure and functions of that organ which, from the enormous bulk of material it is the means of bringing to the soul, takes a prominent place in the part I have assigned to the operation of the senses. If I succeed in heightening a little your already great interest in this organ, or even only in re-animating in some of you the sentiment of happiness which must fill every grateful Child of the Creation, when on awaking in the morning, he joyfully greets the light of day, I shall have earned a rich reward for a trifling exertion.

Look at Figure I; suppose, that the brain which reposes in the cavity of the cranium, and is the bodily organ of consciousness, runs off at one spot of its complicated structure, into a *cord-like process*, which lengthens till it reaches the surface of our body, when it then spreads out again in an umbellar form. Further, imagine this whole process including its roots, endowed with a specific sensitiveness, by virtue of which it responds with a *luminous sensation* to every irritation applied, and you have a fundamental idea of the *nervous* part of the visual organ.

Plate I.
A. Brain
B. Visual nerve
C. Retina
X. Root of the optic or visual nerve



Before proceeding further let us first become better acquainted with these parts. A indicates the brain; B the aforesaid process, or in other words the *optic nerve* which, passing through an aperture in the cranium, stretches on till it reaches into the orbit, where it spreads out into that expanse C, which under the well-known term of *retina* turns its surface to the outer world. Lastly, X is the point where the process is in-

serted in the brain, the letter meaning to indicate the still unknown extent of its dimensions.

When I said above, that every point of the whole mechanism on being irritated, produced a luminous sensation, or a sensation of light, I meant that the irritation was conducted to the brain and called forth this sensation in that sole source of conscious impressions. It is the same irritation coming in contact with the organ of consciousness, which we observe in the nerves of touch, with this difference that, in the above case, the *quality* of feeling differs; it is the peculiar one of the *luminous* or *coloured.* The mere producing of this sensation of the luminous does not in any way depend on the *nature of the irritation.* Squeezing, pinching, pulling, chemical, or electric irritations which give rise to the sensations of warmth or pain in a nerve of touch, call forth in the above-mentioned apparatus, by virtue of its specific sensitiveness, only a feeling of light, accompanied by neither pain nor heat.

You ask perhaps, how men have arrived at the certain knowledge of these things, seeing the mechanism in question by its local position is almost entirely removed from any direct investigation. First then, the umbellar expansion of the optic nerve, the retina, enables us to make experiments; this retina as we shall soon see, being in such close contact with the eye, the optical part of the visual organ, it is therefore accessible to every sort of mechanical irritation. You have yourselves consciously or unconsciously, often made such experiments, when for example, you watched the circles and sparks of fire and light, which become visible on your rubbing or pressing your eyes through their lids, or even perhaps on coming against them with a hard substance, — your

own clenched hand, for instance. Here the eye itself as an optical apparatus, remains passive. Just as a man who sees, is aware of the phenomena even in the deepest darkness, so is also a blind man, as long as the retina is endowed with its specific sensitiveness or sensory power, by means of which it is enabled to respond to every irritation with the sensation of the luminous. Even after blindness, this dancing of sparks of fire and light may be kept up by continual irritation in the eye to such a tormenting extent, endangering even the just mental balance that, in order to prevent it, we usually cut the optic nerve just behind the eye. Thus, the link between the retina and the brain is broken, and the sparkling and scintillating ceases, quite in the same manner as does a feeling of pain when we destroy the nerve of touch in question, and thereby interrupt all communication between the point of irritation and the brain.

Although less directly, the optical nerve, no less than the retina is accessible to our observation. Hence we ascribe certain scintillations visible to us in a rapid motion of the eye, to a twist of the nerve; surgical operations, dating from a period when narcotics were not employed in the performance of the more cruel scientific sleights of hand, have likewise confirmed, that contact with this nervous cord, produces only sensations of light, not those of pain.

Lastly, we can point out the seat of the root, or as we call it the central termination of the optic nerve, by anatomically tracing the fibrils of the visual nerve into this section or division; and partly too, by an analysis of all the phenomena observable in both healthy and diseased states. When the brain has been excited by any narcotic, and the irritation is transmitted to aforesaid section, there arise sensations of light,

which combining with a simultaneous excitation of ideas of luminous objects, are transformed into what we call phantasms. The same thing takes place when the blood, as in fever, grown too warm, not figuratively, but as measured by the thermometer — heats the brain; or when the gentle but unceasing excitation to which that part of the brain is subjected by the beating of the pulse, by the circulation of the humours, and by the chemical changes of matter, can no longer be forced into the back ground by the dominating power of sensory irtations. And thus it is with our visual impressions during dreams, or even in a half-waking condition.

But all this does not constitute any relation between sensation and the objects of the external world; in a word, it does not constitute any *sensory action.* We are quite right when we transplant into our range of sight the gay visions that surround us in the intoxication caused by opium; the comic phantasmagoria that hashish conjures up; the compact shapes that belladonna brings so near us, or the airy forms seen in our dreams, and the scintillations produced by pressure, seeing they all proceed from irritation of the special sensory power, and farther, from its being indifferent to the brain whether it receives its impressions from the results of direct vision,— which will herafter call for attention,— or only from direct internal influences. The conclusion alone would be incorrect, viz., that those things, which are presented to the imagination really do exist; because we here miss the handle to the conclusion, I mean, the objective action of the senses. All those operations therefore, which proceed from direct irritation of the nervous part of the visual organ, *without the medium of the eye and of light*, under the term *subjective vision*, are opposed to those phenomena pro-

duced by the media of eye and light, and known as *objective vision.*

Great as are the influences of this subjective sight for the refreshment of our brain during sleep, and powerfully as they affect the temperament of the blind, just in the same degree are they utterly unimportant for our connection with the things of the outer world. The yellow light, which floods our field of vision on rubbing the retina, can as little be used to light up objects, as we are able, much as we should like it, to transplant our sleeping visions into reality. Hence, when some years ago, a man pretended to recognise a delinquent*, who had attacked him in the obscurity of the night, by the sparks of fire produced by a blow on his eye from a stone, and thereon founded an accusation, we assert the accusation was unjustifiable, and laud the wisdom of the judge for casting doubt on the testimony, all the more, as at that time the authorities consulted did not declare against the impossibility of the fact.— Baron Münchhausen with his admirable presence of mind, went still farther than the above-mentioned plaintiff, in the use to which he put those same visual sparks; for, when attacked by bears in the night, he not only struck out light enough by which to prosecute the chase, but fire too, for their guns, with the same blow; departing at length from this practice, only on account of the pain it caused him in his eye. But the position altogether, which the genial Baron also in other respects, took to the laws of nature, was quite exceptional!

We cannot entirely overlook the question, viz., whether

* Henke's Zeitschrift für Staatsarzneikunde, Vol. 26, p. 266, anno 1833.

sensations of light can be produced with the assistance of any other mechanism in the body, but that of the visual nerve. This query must be answered in the negative, if it is understood in the sense that, the intervention of the part wherever situated, may be dispensed with in the evoking of those sensations; but in the affirmative, if strictly confined to the point where sensation originates. As only this part is endowed with specific sensory action, so the irritation of the same can alone quicken impressions of vision; but this irritation may be imparted to it by other parts of the brain, or by other nerves. It has been already stated, that irritations of the brain produced by narcotics, are transmitted only by proximity to the terminal extremity of the optic nerve. At the same time, it may be, that the irritation proceeds from another nerve, from a nerve of touch, or of hearing, for instance, and penetrating to the brain, affects it so strongly as to send on the concussion to the centre of the optic nerve. It is this that takes place when, after having listened to sounds repugnant to you, you are seized with certain sensations in the nerves of touch, for instance, in those of the tooth; or, after having gazed into the bright light, you become aware of a tickling sensation in the nose causing you to sneeze. In a word, it is here question of so-called *sympathy*, to be explained by transmission of the irritation from one nerve to the other.

The disposition to such sympathetic sensation is increased by a general irritability of the nervous system; while in a calmer, in a recruited state of the nerves, the excitations run more regularly in those paths directly affected by the originating causes. In this manner the domain is widened of those indirectly-provoked visual impressions which preponderate in circumstances of sickness and disease.

I need scarcely add after what has already been said, that in those indirect visual sensations, as in the direct excitation of the mechanism of the visual nerve, only subjective sight has been treated of, subjective sight cut off from every relation with the outer world. We are quite ready to attach credit to the fact that, at exhibitions of somnambulism and such-like "hocus-pocus", when the natural irritability of nervously disposed individuals is heightened, subjective visual impressions are produced in an unusual degree. Should however, any connection with surrounding objects be founded on those results, or transmission of the specific sensory action into other paths supposed; if, for instance, to mention one among many, a man transmits to the skin of the abdomen the power of producing objective visual perceptions, say, such as are necessary for reading, then it must be admitted that such assurances are to be ranged in the same category of physiological blunders, as the afore-mentioned assertion of the plaintiff, and Münchhausen's hunting stories.

By what means then, does the mechanism of the visual nerve, which we have hitherto regarded merely as the mediator of subjective sight, become a practicable bridge between our ideas and the outer world, and a medium of the true and accredited *operation of the senses?* I answer, by a normal relation to a definite irritation proceeding from an object. This excitation, which we might call the *adequate sensory irritation*, is *light.*

Let us linger some moments to consider the general relation between light, and the organ of sight. Unable to dis-

cover with certainty the nature of light, it is explained in physics as being the undulating motion of an elastic body called ether, diffused throughout the universe. According to this, the irritation by light represents in a certain measure, the shock of the undulations of ether on the irritable nervous matter, and thus, at once takes its place clearly enough, among the mechanical excitations mentioned above when speaking of subjective sight.

Now, it will seem strange and almost contradictory when we say, that just the cord of the optic nerve, which on any mechanical stimulous emits at once the sensation of the luminous, is insensible to the undulations of the ether, and that the peripherical expansion of the retina is alone susceptible of irritation by light. This peculiarity has to do with the arrangement called the *terminal apparatus*, with which it is now proved every nerve is furnished. The *nervous cords* themselves are pre-eminently conductors; their irritation, when it does take place, necessarily produces impressions which come under the head of qualitative, for the eye therefore, of the quality of luminous sensations; those impressions do not however, stand in any closer relation to the adequate sensory irritation, and may be, as far as we are concerned, quite devoid of sensitiveness.

According to the results of farther physical experiments, light is the same species of motion in the ether as warmth; only in order to produce the irritation on our retina, the undulations in respect to their rapidity, must be confined within certain limits. Relatively they possess the greatest velocity in the violet-coloured part of the spectrum, and the relatively least, in the red. In the same proportion as the velocity of the undulations in the air diminish, does light become invisible,

and only dark rays of warmth are emitted, such as for instance, we see given forth by moderately-heated lamps of metal, while on its being more highly heated, from the increased rapidity of the atmospheric undulations, it reaches the glowing-point, that is, it emits rays of red light.

From this we see, that the idea of light depends essentially on the organisation of the retina. Were it different from what it is; did it possess any susceptibility for atmospheric vibrations of a less degree of velocity than those at the red end of the spectrum, then we should call *that* light which we now term a dark warmth; a lower degree of irritability in the retina, would on the other hand circumscribe the idea of light. Whether the former state occurs among the lower animals, science has not yet been able to determine, but the latter we have actual occasion to observe in certain cases of of natural colour-blindness, in which for example, the susceptibility of irritation in the retina, is quite undeveloped for the extremest red of the spectrum.

Now, while the light which issues uninterruptedly from external objects irritates our retina variously according to its colour and power, we likewise become aware, that the impressions made on us by the luminous object is also very various, and herein lies the first link of connection with the outer world; and this it is which enables us to conclude, whether we have a dimly, or brightly lighted outside world before us, and to say which colour dominates in the light streaming in upon us.

But it is only the visual organs of the lower animals, which, so to say, lose themselves in such a general and vague relation to the surrounding ocean of light and colour. That

visual organ which occupies our attention, has a far higher design to serve, viz., to awaken a perception of the separate objects, and of their peculiar forms and colours. Were the retina as you see it in Figure I, a flat surface curving outwards, then indeed, such a design could not be fulfilled; for every part would receive light from all the points of the outside world; and as the irritation of every separate part would admit of no closer relation to any one fixed point in the external world, so the excitation of the entire retina, and the sensory impression depending thereon, would refuse to acknowledge any such relation. In order to fulfil this condition, every individual point of the retina must enter into a separate and individual relation with the light proceeding from a point beyond it; nor till this takes place can the irritation of each separate spot of the retina produce a peculiar impression, at once corresponding to, and discovering the presence of the object-point; in short, according to the optical expression for such a relation, *a picture of the outside world* must be painted on the retina.

And this is indeed what takes place. As on the one hand, the retina stands as the terminal apparatus of the optic nerve, thus does it on the other hand, act as a shade subservient to optical purposes; a screen, or a shade on which a perspective picture of the outside world is projected. If you compare it with the dull glass on which the picture in the camera obscura falls, or the prepared plate in the photographer's camera, you have a correct notion of what I mean. As in the photographer's camera, the picture falls on the sensitive plate, and is impressed on it by means of chemical changes produced by the light, so in the eye, it falls on the sensitive plate

of the retina, whose irritations are telegraphed to the brain in due form.

We henceforth have to consider this *image painted on the retina*, as the real object of the *operations of the senses.* To be sensible of the impression of the image on the retina, by virtue of the specific power of the senses, as of a luminous and coloured impression, to comprehend its source—and that which constitutes it,—is what we term *seeing.*

But how does the picture imprint itself on our retina? This is done by an optical apparatus close behind the retina and in connection with it; and in short, by means of that mechanism known to us as the *eye.*

If we compare the retina with the sensitive plate in a camera obscura, we shall perceive, that the eye has indeed an undeniable resemblance with this well-known optical instrument, a resemblance to which Porta, the inventor of the

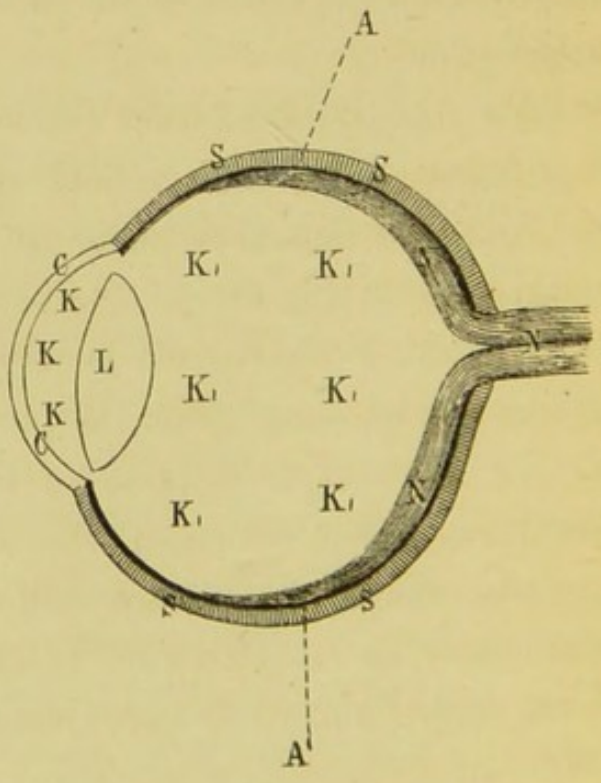


Figure II.
S. Sclerotic. — C. Cornea. — L. Cristalline lens. — K. Aqueous humour.— K'. Vitreous humour. — A. Choroid. — N. Optic nerve and Retina.

camera obscura, called attention, although according to him, the image was not produced on the retina, but on the crystalline lens, which is considerably removed from the retina. Keppler was the first to correct this error. A camera obscura is essentially a box painted black in the inside, with an opening fitted with a collective lens, turned on the objects of the outside world, and which receives the images produced by this lens on the wall behind. In order to show us the image, the one side of the box is replaced by a dim plate of glass. Now cast a glance at Figure II; and first suppose the box to be round; next, instead of the wooden wall, an organic tissue; and the window glazed with a transparent organic coat or tunic, instead of with a crystal lens, and which fulfills the same purpose as a collective lens, and strengthened by one or more lenses placed one behind the other. Further suppose, instead of the blackened inside of the walls of the box, the organic sclerotic coat overlaid from the inside by a second dark coloured tissue; and lastly the retina at the farther end as sensitive plate, and you have certainly an imperfect, but still, as far as an outline goes, — a good general idea of the chief parts of the eye.

To the clearer understanding of these parts, the figure is provided with letters.

The tissue marked at the different sections with an S, is the enveloping tissue called the *sclerotic* or sclerotic coat.

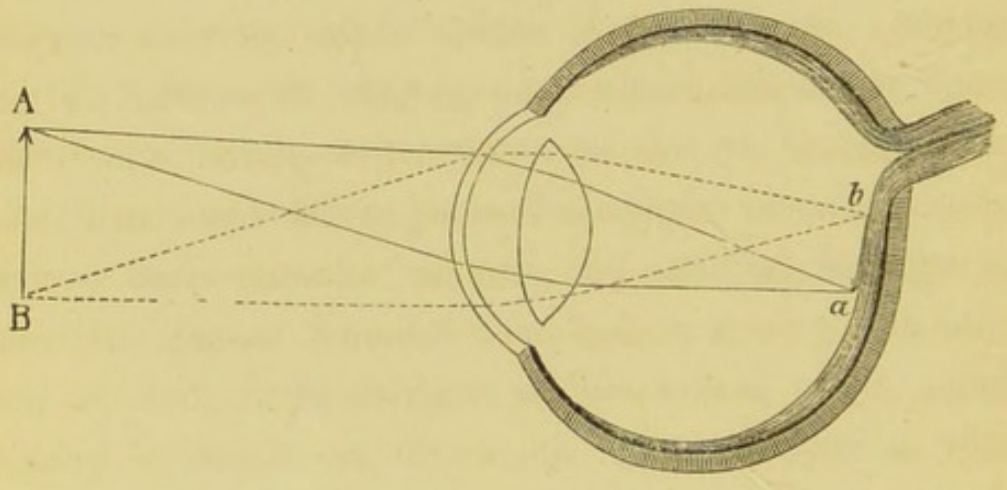
To the front overlapped by the above, lies the transparent tissue, the *cornea*, C, which represents the window, and at the same time, contributes essentially to collecting the rays of light. At the back, enters the already known optic nerve, which, spreading out to right and left within the sclerotic, receives the name retina, likewise marked with an N.

The chief business of the *lens* L, lying well back, and rendered perfect by the humours (K aqueous, K' vitreous), which fill the spaces or chambers, is the refraction of the rays, whose admission has already been prepared by the cornea,

And lastly, overlaying the interior surface of the sclerotic, is the *choroid* with its pigment, being the substitute for the black paint in the camera. You find it marked with an A.

Now if this eye with its cornea, like a camera obscura with its window, is turned on the objects of the outer world, we shall behold what Figure III shows us: The light pro-

Figure III: A B object of sight, *a b* image on the retina



ceeding from a point A, beyond the eye, throws a pencil of rays on the cornea, this is already refracted here and there on the surface of the lens, but in a manner so as to collect all its rays again in the one point *a*, of the retina. This *a* then, is the image-point of the object-point A. In the same manner, *b* becomes the image-point of the object-point B, and all the object-points between A and B will find their image-points on the retina between *a* and *b*. In a word, an *inverted perspective* image of all the objects comprehended in the space AB will be found reflected on the retina.

Let us now examine a little more closely the shortly-before mentioned structure of the eye, together with the object it is designed to serve, taking the separate parts in the direction from without inward.

The *sclerotic*, a stout and not very elastic coat, wants no farther description. On the other hand however, the *cornea* as the transparent window, deserves your whole attention. In the construction of the cornea, nature has had to overcome exceptional difficulties. If you remember how apt every organic body exposed to the air, is, to fall a prey to desiccation, under the influence of which the optical homogeneousness, on which transparency depends, is lost, you will readily acknowledge the amount of resistance the cornea is enabled to offer. But farther consider, that the cornea does not possess a homogeneous structure, but in the service of the transmutation of matter it consists of five different, partly compound layers; that it hides in its interior, numerous cellular bodies, canals for the passage of the humours, and a network of nerves,— and then assuredly you will not refuse your admiration to the optical excellence of this most indispensable of all windows.

However, the difficult task implied in the structure of the cornea could not be fulfilled without the aid of some extraneous appliances. Thus two movable covers lie over the eye, namely the *eyelids*, whose inner surface is a compound *humourous matter**, a brackish, mucilaginous, fatty solution. After having used our eye for a while, there arises a certain sensation of dryness on the cornea from exposure to the air; the ever-recurring

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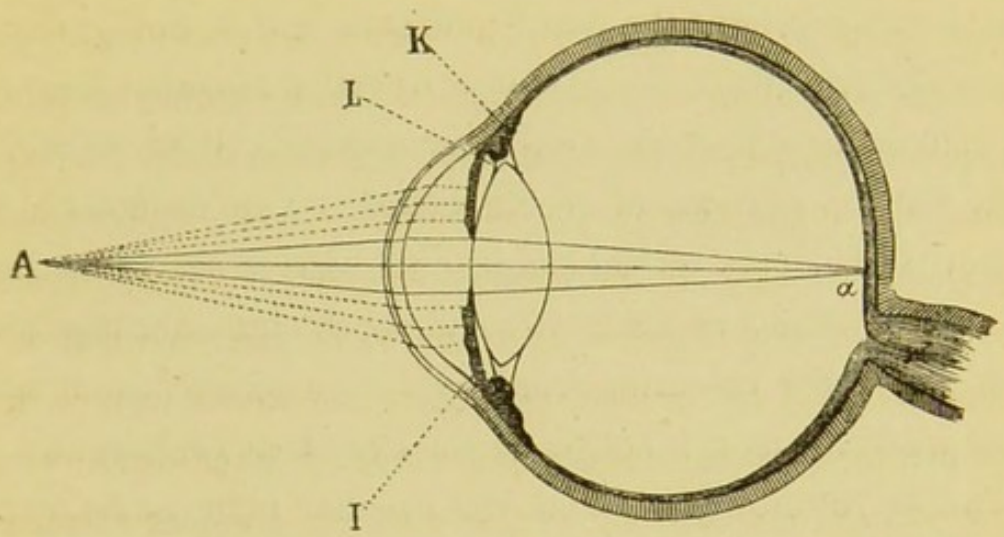
* This matter receives the name of *mixed tears* contrary to the *briney tears* which by mechanic irritation or during weeping flow from the eye.

necessity of renewing the moistness causes us to close the lids, or as we say, to *wink*. This is at least the chief design of the dropping of the lids, which besides lend their aid to the periodical exclusion of the irritation of the sight, as in sleep for defence against the dazzling light, and for protection against the impurities in the atmosphere. The cornea is likewise being continually moistened by the posterior humours. But you will comprehend that, with all the expedients and appliances used by nature, perfect transparency cannot be always preserved, and indeed dull spots are formed on the window of the cornea, and are one of the most widely-spread causes of derangement of vision. Unimportant irritations, which on the surface of the body pass over without a trace, or leaving behind such slight marks as are scarcely noticeable, can unfortunately, most seriously affect the cornea.

Let us now pursue our path from without inwards, going on to the second coat or tegument, the *choroid*. This we compared to the black coating of paint in the camera obscura. Thinking of the dazzling and delusive visions which are a consequence of the gradual consuming away of the pigment in the choroid, or which accompany the entire want of it, as with the albinos, we cannot doubt but that one essential design of this tissue is, to intercept the scattered rays. But apart from its office of conducting nourishment to the eye, and secreting the humours by means of its numerous blood-vessels, the choroid has a *second optical* design to fulfill, which now brings us into the regions of the eye well-known to you, and which are mostly regarded as the characteristic signs of the eye.

As you will perceive from Figure IV, which gives a section of an eye from life, the choroid, after having faithfully accompanied the sclerotic to the edge of the cornea, goes on

Figure IV: The same parts as in Plate II, besides: I Iris. — K Ciliary muscle. — L Suspensory ligament of the lens (zonula).



expanding anteriorly, and from henceforth bears another name, that of the *iris*, or as we might say, the *rainbow tissue*. As this process, which likewise contains a quantity of pigment, lies behind the transparent cornea, it can be observed in all its minutiæ; and on account of the rayed arrangement adopted by its fibres, it is frequently called by the unprofessional, the eye-ball, or star. The iris is broken in the centre by an opening to which we apply the term *pupil*, being the *visual aperture*. It usually seems to be black.

The presence of the iris then, greatly diminuishes the extent of surface designed for the reception of light; the whole pencil of rays that falls on the cornea as supposed in Figure III, not reaching the retina, but only as shown in Figure IV, on that section of it which enters the pupil. Though much of the volume of light is thereby lost, the restriction is highly beneficial, by sharpening the image on the retina; for the refraction of the rays is much more equal in the centre than towards the margin.

The iris however, has a still more important function to

perform. It *regulates the entrance of the light*, being furnished with a muscular apparatus (ciliary muscle), which provides, that in strong light the pupil contracts, and in duller, expands. Thus the iris plays the part of a so-called movable diaphragm, a common appliance in optical instruments, used to dull the light for the purpose of seeing better. You cannot but have observed this play of the pupil, and how it accommodates itself to the volume of light; nor can you be ignorant that the iris with its varied colouring from light-blue to deepest brown, is what we know as the colour of the eye. It is perhaps less well-known to you however, that the peculiar pigment required for the darker colours of the iris, comes only as we advance in life, and that therefore, we all commence our earthly course with blue eyes; a fact already known to Aristotle.*

The *crystalline lens*, which is held fast in its place by a very fine tissue, as shown in Plate IV, from the curve of its surface, and its strong power of refraction, plays an important part by conducting the collected light to the picture on the retina. It has however, another and extremely important design which must here be carefully considered.

The requirements made on an optical instrument depending on lenticular effect, are different according as it is expected to project images of nearer or more distant objects. The light with very divergent rays, and proceeding from near objects, is collected to a picture behind the lens, while that of the distant objects falls with almost parallel lines. To return to the camera obscura, you must draw out the tube with the lens, in other words remove the latter farther from the intercepting

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* De generatione animalium lib. V. cap. I. p. 407. line 49 and 50. Ed. Basil. anno 1539.

plate if nearer objects are to be impressed, and on the other, push it in, if more distant ones are wanted. The same effects might be produced at equally the same distance by simply substituting lenses of different power. Now, the human eye has to fulfill the requirement of projecting clearly defined images on the retina, whether they are but a few inches off, or at an immeasurable distance. This eye of ours being strictly subject to lenticular laws, either the space between the lens and the retina must have the power of varying, or the lens itself by a change of form, exercise now a stronger, now a weaker power of refraction.

Long has science groped in those two directions, expending a wealth of ingenuity and acuteness on the search, in order to explain this remarkable power in the eye of accommodating, or adjusting itself to nearer and more distant objects, and the conclusion has at length been arrived at that, this power rests on a *varying curve of the lens.**

In order to effect this, a great degree of *elasticity* chiefly of the outer capsule, was obviously necessary, and we find this requisite complied with by an admirably delicate structure — see Figure V— according to which its density reaches the

Figure V:
Cristalline lens with its layers.

minimum at the periphery of the lens, while its aggregate

* The mode of procedure is now known down to the last and most minute detail. The surfaces of the lens give back extremely delicate reflections, which with the proper aids may be measured in the living eye, and from the size of which the curve may be calculated as in convex and concave mirrors. As auxiliary of this change of form there is a peculiar agent — a muscle embedded in the choroid (K, Figure IV) which has the power of contracting and expanding the suspensory ligament of the lens.

power of refraction is increased, as if it were composed entirely of the strong refracting substance of which the centre consists.

As the power of accommodating its focus rests on this quality of the lens, it is necessarily accompanied by a loss of elasticity with increasing age. The eye of a man of sixty, that sees distinctly at a distance, is unable to distinguish an object five inches off, and if against all rule it sees sharply at five inches off, this benefit is counteracted by the inconvenience of seeing distant objects with great indistinctness. The gradual hardening of the lens is accompanied by a decrease of power of adjusting its focus, and is even subject to such small individual fluctuations that, by an exact calculation of its play *, we may sometimes arrive at the most indiscret conclusions respecting the age.

Should the lenticular elasticity no longer admit of a sufficient scope for refraction, we must then either adjust the distance of the objects, as we see a far-sighted iudividual do, by holding the book proportionably farther off, or we must afford the eye assistance by accommodating it with movable auxiliary lenses, so-called *spectacles*, which replace the lost power of adjusting forms to the natural eye. This power of accommodating the focus, disappears beyond recall, if the lens has sustained an injury, or if we remove it entirely from its having grown turbid, therefore useless. This takes place in the operation for the cataract, which malady is a diming of the sight from a thickening of the lens.

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* The diminution of the play does not commence in the second period of our lives, but as Donders in classical works on this subject has proved, in a regular manner from childhood onwards.

Having herewith descanted on the excellences of the lens, we must, unless we are to pass for mere blind panegyrists of nature, not omit to mention that the lens is not altogether free from optical irregularities, which assume the most various forms. Chief among them is that, when the focus of the eye has not been perfectly adjusted for seeing in the distance. Those of you who are short-sighted, on looking at a distant street-lamp, perceive instead of the clearly-defined image, an irregular circle of light, and you will at the same time, observe within that circle, a number of peculiar rays and dots which are nothing but irregularities in the lens, i. e. the reaction of those irregularities on the retina. Even an eye whose sight is quite normal, makes an analogous observation if it directs its gaze to a very fine point of light, as for example to a star. Both the star and the atmosphere are equally innocent of the small beams that radiate from it; they are the rays of our own lens which we transplant to heaven. So little aware are we of what takes place in the depth of our sensory organs, or in the immeasurable distances of the universe!

The spaces between the lens and the cornea, as also between the lens and the retina, are filled with a liquid medium, called *humours*; the latter, which constitutes by far the largest chamber of the eye, is filled with a gelatinous substance called the *vitreous humour*. This medium likewise contributes essentially to the concentration of the rays of light, as, lying between two curved partitions (septa), they exercise a similar influence as the lens.

The vitreous humour optically speaking, is however not pure; small granular, or wavy forms, which all of you at times have seen hovering within your field of view, and which pursues so many a hypocondriacal man on his summer-trip

to a watering place, is occasioned by shadows thrown on the retina by a partial, delicate opaqueness in the vitreous humour. Those bodies are so light as only to be perceptible, either in certain effects of light, or on a peculiar exertion in the straining of the attention. By a simple experiment it is possible to make every person acquainted with these guests of his field of view, the so-called *mouches volantes*; only one must be prepared for those formerly overlooked, but once honoured with attention, never again stirring from their post.

In order likewise to preserve space for the play of the above-discussed variations in the form of the lens, in the act of adjustement, it was necessary to surround the lens with a liquid or elastic medium. That the acqueous humour bears a part in moistening the cornea, has already been stated, but in the voluminous vitreous humour we behold the *regulator of the shape and tension* of the eye. Such an auxiliary medium is of urgent necessity to keep up the regularity of refraction, the quality of tension in the retina as a sensitive surface, and the action of the optic nerve. Some years ago, I was happy in having been able to demonstrate that a comprehensive range of diseased conditions and also blindness, the causes of which had been successively sought for in the most different parts of the eye, simply arose from too great a tension being exercised by the vitreous humour, — a discovery which imparted so much the more pleasure, as a suitable remedy was likewise at hand.

Let us once more imprint on our memories from the model of a magnified eye, the positions and dimensions of the different parts, which revision will at the same time offer an opportunity for making some additional remarks *. For the

* The model used here for demonstration (as far as p. 31) measures

present, I begin with the cord of the optic nerve which, as you perceive, does not enter the sclerotica quite exactly opposite to the cornea. This part, as well as the larger posterior chamber of the eye is embedded in the orbit, and is therefore not visible externally; while on the other hand, between the lids, you remark the white of the eye which is the anterior chamber of the choroid; next the transparent cornea, and away through it the coloured iris with the pupil in the centre.

The black appeaance of the latter used to be ascribed solely to the dark layer formed by the choroid for the interior of the eye, absorbing all the light. More patient and minute investigations have however proved, that the pupil derives its blackness only partially from the above circumstance, and mostly from the refraction of the light. Helmholtz's keen spirit of investigation has succeeded in banishing that darkness from the pupil of the human eye. By a simple arrangement called the *speculum oculi,* he uses the light which is reflected from the deeper parts of the eye to illuminate the whole of the interior, as also the image itself projected on the retina. This invention exercises an influence not only on the peculiar branch of the occulist, but likewise on the broad field of medical investigation, seeing it affords an insight into the optic nerve, a direct process of the brain, and other structures, which along with their analogis were hidden from observation in the body.

The dimensions of the eye-ball among strong-sighted individuals, is more equal than you perhaps imagine. The apparent differences of size lie almost exclusively in the shape

about 10″ in diameter, the coats of the eye are of tin coloured from nature, the cornea, lens, and vitreous humour of glass.

of the slit of the lid. If it has a wide slit, it affords a view over a greater part of the eye-ball, and we think it bigger, simply because we see more of it. In the same manner, our judgment is deluded by the different degrees of prominence of the eye; I here refer to the manner it is placed in its orbit; I mean according as it is more or less deep. A staring or protruding eye impresses us as being larger although it is mostly only pressed forward, while in advanced age, or in consuming sickness, the sunken eye is thought smaller.

If the eye really is larger, then the distance between the cornea and the lens will be greater, and if the effects of the refracted light remain the same in the latter, the image will no longer be projected on the cornea but in front of it. And this is what really takes place in that wide-spread malady called *short-sightedness*. Here we have especially to note that the mean axis of the eye is too long. There are others called *far-sighted* eyes whose visual axis is too short, the image for such eyes falling behind the retina. In order to re-establish the conditions of keen vision in both cases, the effects of refraction must be diminuished for the short-sighted, by diverging or concave glasses; for the far-sighted, by collective or convex glasses. Those conditions have nothing to do with the want of the power of adjustment of focus as aforementioned. If you correct the defective construction of the short-sighted eye with a concave glass, and that of a far-sighted with a convex one, the lens — its mobility being preserved—can with their aid accommodate itself to near and distant objects, what neither an old man, deprived altogether of the power of adjustment, nor an individual who has been operated for the cataract, is capable of doing, either with the naked eye, or any glass even constantly used.

Let us now pursue the analysis of the model in the same order as at the outset. First then fold back the cornea with the anterior section of the sclerotica; the margin of the eye to the front is now interrupted by the pupil, and is for the rest formed by the tissue of the iris, and the anterior section of the choroid. The space (at present wanting) in front of the iris-curtain, was filled with aqueous humour, which you must suppose as having escaped. Let us now remove the posterior half of the tissue of the visual nerve; the whole eye will then be closed up by the passage of the choroid and iris, which now meets with no break, except anteriorly from the pupil, and posteriorly from the entrance of the optic nerve. If now, as with the sclerotica, we fold back the anterior division of the choroid along with the iris, in doing which we have an opportunity of convincing ourselves of the true nature of the pupil, and that it is indeed an opening, we then come upon the hard lens lying behind. Taking this away as also the gelatinous vitreous humour, we at length remove the posterior section of the choroid, and have nothing left but the optic nerve, and the retina. Thus we have again arrived at the starting point of our reflections; and it only now remains for me to bring before you the retina, being the bearer of the image projected by refracting media.

Before however, entering on this division of my subject, let me call your attention to a few fundamental processes in the act of seeing. First in order is the following, that the picture or image on the retina is perfectly sharp only at on particular spot situated somewhat beyond the optic nerve, and exactly opposite the centre of the cornea. The light which falls along the main axis of the eye, converges at this point. This said spot in the retina is marked by a small

hollow. For the rest it is filled up with a structure of its own; and we have all reason for assuming that it furnishes the most exact perceptions, not only on account of the greater optical sharpness of the image, but also on account of the higher energy or activity in the sense of sight, with which it is endowed. It is this spot we make use of when we desire to go into details; for, if we wish to examine closely into the nature of an object, either we approach it to the eye, or bring the eye to bear on the object; but in both cases, in such a manner, as to cause the image to fall exactly on the hollow of the retina, or as we also say, on the spot of *direct vision.* This arranging of a position for an object is what we mean when we speak of adjusting the eye.

The images which are not projected on the spot of direct vision are not sharp; for the necessary light falls on the refracting media more or less obliquely. This, and the decrease in the activity of the sight from the hollow to the sides, explains how the objects, the farther they are removed from the fixed point, appear with so much less clearness and sharpness of outline. *Indirect*, or *excentric* vision as it is termed, makes us aware simply of the presence of objects, by giving us some notion of their shapes; but we are unable to distinguish even the biggest letters, if the image of them should fall only one hair's breadth off that one spot in the retina. In reading, the eye must constantly move onwards to the end of the line, the single letters thus gradually imprinting themselves on the direct point of vision. On the other hand, indirect vision offers so to say hints for fixing the object in our eye, it warns us of, and prepares us for the object previous to our devoting our whole attention to it, and it is farther of use in procuring us a *wide survey*, by inabling us to see

and examine what lies before us. There are some who only possess direct vision. Any one can put himself in the place of an individual so afflicted, by holding a long tube of small caliber to his eye. You naturally distinguish the most minute objects enclosed within the restricted range of vision; but deprived of the lateral impressions, you could not guide your steps in the street. In short, you must fancy the image of the external world that is imprinted on the retina, like a picture *highly finished in the middle*, and only *roughly sketched out at the sides.*

The farther the pictures on the retina are removed from the spot of direct vision, in the same degree naturally enough, are the corresponding objects distanced from the fixed point; and just as the retina has a definite expansion and a margin, so the distance from the fixed point at which the objects may be perceived by excentric vision, has also its limits. When looking straight before you, you can just perceive a hand which stretches down the whole length of the face, in the direction of the temples. This is the extremest point from which it is possible for light to fall on the retina; but if you attempt to go beyond it, the hand disappears, the image of it not being any more projected on the retina. Now, the combination of all the extreme points from which with a set eye, impressions may be received, forms the frame of the field of view, and what is within this frame, is itself the *field of view.*

This space immovable as regards the head, and called the field of view, becomes the arena to which both those excitations produced by the senses, and those belonging to subjective sight, are transposed; and this transposition always takes place in the same direction as that, which a regular act of

sight, the source of irritation for the said spot in the retina would in any case lie. Although long experience has taught us it is a delusion, still we always place the image projected by a mirror, behind it, because the reflected light falls into our eye just as if the object were behind it. But the sparks of fire too, which we produce by pressing our eye from the side of the temples, we seem to see in the opposite side of the field of view, although our own sense of touch convinces us where it is the irritated spot lies; but we do so, because in the normal act of sight the retina is irritated (from the side of the temples) by light falling from the opposite side. By the *action of projection*, the reversed image naturally regains its upright position in the field of view.

A general irritation of the retina unaccompanied by a perception of objects will give us a *light* field of view, and on the other hand, a perfect repose of those parts, a *dark* field of view; for pray, do not confound "seeing obscurely" with "not seeing at all". The former represents the sense of the repose of a mechanism endowed with the power of action; the latter corresponds to the absence of all mechanism whatever. The feeling of darkness therefore, results merely from the expansion of your field of view as opposed to your retina, if I may so say; while behind your back you have the feeling neither of light nor of darkness; you simply miss all sensation of light.

Touching the *size of the images on the retina*, as compared with the objects themselves, I need merely remind you of the rules of perspective. As in this respect there exists absolutely no difference between any other optical image, as for instance, in the camera obscura, and that in the human

eye, the images on the retina will therefore stand in reversed proportion to the distance of the objects. The image of a pencil held a foot from your eye, covers the trunk of the tree before your window, that of a pea at a like distance, the moon in the sky. If we notwithstanding, think the moon bigger than the pea, and the tree than the pencil, the reason is that, apart from our being well-acquainted with the tree at least, our judgment is a combination of the size of the image on the retina, which is directly impressed, and the distance of the object. Now as consciousness is for the most part founded on experience, so just and correct *perspective sight* is in the main something we *acquire.* A child will assuredly not appreciate the difference between the pencil and the trunk of the tree in the same degree as an individual, who by experience has learned to know the value of his impressions. What the child first knows of the moon is, that he cannot reach it with his hand; "but," as I once heard a child say, "mother can reach it down." Other inferences have helped him to this conclusion. We are so accustomed to merely play with children, that we are easily blinded to the full seriousness of such requests.

We cannot however, break off these reflections on the image on the retina, before making mention of a remarkable spot in the background of the eye,— the yellow spot marking the entrance of the optic nerve. From the moderate distance of the hollow of the retina, and according to the above-discussed principles of excentric vision, the images falling on this spot, ought to produce tolerable, if not altogether perfect visual impressions. Instead of which however, all perception whatever, is arrested within the bounds of this spot — it is a *blind* point in our field of view. Most of you

will not have noted this defect of the eye, if I may call it so; and yet you may convince yourselves of the fact any moment.

Place yourselves before a black board, fix your eye on a spot drawn on it, and gradually pass a white ball affixed to the end of a black rod in the direction of the temples of that eye, whose gaze is immovably fixed on the afore-said spot; you will observe the ball disappear entirely at a certain point, and emerge only after some part of its path has been accomplished*. In making this experiment, the second eye must of course be covered, as otherwise the image of the ball would reach the field of view of the one eye, while falling on the blind spot of the other.

The *blind spot* is by no means so excessively small. At the distance of four paces, it would cover a man's head in the centre of your field of view; and almost a hundred moons in the sky would find room within its bounds. When two centuries ago, Mariotte made this important discovery, it caused so much commotion that the experiment had to be repeated before the king of England in 1688. In the endless variations

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*) A pack of cards being in the possession of almost every person, I recommend the following method of experiment. Shut your left eye, hold the two of clubs up before your right one so that the surface of the card lies parallel with the surface of the face, and the diameter perpendicular or a little inclined to the right. If in this position you gradually increase the distance between your eye and the card, taking care to fix the point of intersection of the two limbs of the cross in your eye, the right cross disappears entirely, at a distance of from 8 to 9 seconds, and only the white ground is visible in its place. If you do not snceed in making the cross wholly disappear, then increase or diminuish the distance at which it mostly takes place, also the inclination of the card by a little, thus discovering and adjusting the most favourable position for the experiment.

of the experiment, the remarkable fact only received a new confirmation. For the rest, this discovery had almost proved fatal to the doctrine of perception; for, as at that time the optic nerve and the retina being considered as essentially the same, one might deduce a priori, the inference that just at that point of entrance at which all the conducting fibrils converged, a heightened sensibility might be argued. But now proving to be insensitive, the retina itself could no longer be regarded as the regular conductor of the sensation of light. And this was the conclusion to which Mariotte did arrive, transplanting the sensibility to the choroid behind the retina, till at length Bernoulli and Haller again restored it to its rights.

This apparent enigma is explained by what I took occasion to tell you (see p. 19) of the general relation of light to the visual organ. The part the optic nerve plays is only that of a conductor, while the sensations of the vibrations of the air, as also of the specific sensory irritation, is committed to the retina or more correctly speaking, to its external layer.*

Another question which you would be fully justified in asking in this place, is, why does the existence of the blind spot usually escape our attention, even in those cases when we use only one eye, and thereby deprive the gap of the other, of its cover, i. e. of the second image. The chief reason is that, as the gap is regularly situated in the same spot in the field of view, the *idea* has learned to fill it up in the most natural

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* Science has proved namely, that the retina as well as the optic nerve, consists for the most part of *conducting* elements, and that only a peculiar ribbed layer, which separetes it from the choroid, plays the part of the *terminal apparatus*, or of the assimilator for the adequate sensory irritation.

manner, and as is most suitable for the connection of objects. For instance, I draw the figure of a cross on the board, and fix my eye on it, so as to cause the centre district of this figure enclosing the point of intersection, to fall on the blind spot; in this manner I believe indeed that I see a cross, while in reality I only see what lies beyond; fancy supplementing the rest. The cross is a commonly-known figure, and when any two lines take a perpendicular direction towards each other, they as a rule, really do intersect each other. The best proof of this being the case, is that, when you obliterate all that lies within the district, you still continue to see the cross; and, to make the experiment more elegant, if you place some photograph in the empty space, you do not perceive it, you still continue to see only the cross*. You have here then a conjunction of objective sensory action and subjective production, apparently with the help of the central extremity of the optic nerve, which is highly significant for the whole doctrine, and which to a certain degree combines what I have been endeavouring to explain to you on both of those branches of our subject.

Hitherto we have examined the eye in a *quiescent* state; but you know that it *moves*. It must, were it only for the purpose of directing the look; for it would be at once troublesome and awkward, if in order to look straight before us, we were compelled to move our head. A higher object is designed by this power of motion in the eye, and it is to enable us to regulate the *relative* position of *both* eyes, enabling them to alternate according to the position of the point

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* For this experiment the *two of clubs* can again be used. Let the directions given in the former note (see p. 38) be followed only lengthening the arms of the right cross by two very strikingly thick strokes.

mutually agreed on, a requisition with which immovable eyes would be unable to comply.

In *moving* the eye, the organ itself is not displaced, it simply rotates round a centre of motion situated in its own middle. The mechanic has proved that for a globular body, this can be most perfectly effected by means of three couples of forces which rotate round it, moving on three axes corresponding to the extent of space. In like manner, we find the eye has been provided with three pairs of muscles partially fulfilling this condition, and designed to aid in its motion. With their assistance the eye can move to the right and left, up and down, within certain extreme points which frame in the field of direct vision or *range of vision*, not to be confounded with the afore-mentioned *field of view*, the arena of indirect vision.

The directions we cause our eyes to take, are, apart from the act of seeing, interesting as the *symbol of the look*, the glance. If, as we have seen, a certain direction of the eye is necessary for the fixation of an object, still the choice of the point fixed on, is left to our option. There are moments, in which we really fix a certain point of that object with which our fancy is busied; there are others in which we let our eye wander over it, measuring its outline as it were, or going round it; others again, when we do not look at it at all, but on a fixed object of the fancy before or behind the actual one; and lastly, such in which the eye moves in the indefinite distance with no particular aim. By the raising or lowering of the look, the eye exercises as we know, a mighty influence on the expression; also by the relative direction of both eyes, and lastly by the bearing of the eye-balls and eyelids towards each other, and relatively to the pupil. From

an analysis of all these relative positions are derived the principles of physiognomy, the discussion of which I regret being compelled to pass over.

As indispensable for the completion of our subject, there remain still a few words to be said on the looking with *two eyes*. Although an image is projected on the retina of both eyes, yet as a rule, we see only one object. This depends on a faculty with which we are endowed of blending the double impression made on us, *if certain normal conditions* are fulfilled. It will become clear to you from the following experiment, that this cannot otherwise be possible. Direct both eyes to one object, lay a slight pressure with your finger on the under lid of the one eye, thus somewhat disarranging its position, and you will at once be made aware that the one image has thrown off a second, and that now all the objects in your field of view seem double; you have now the divided sensation of two retina-images. In order to blend the two impressions, they must both fall on the points of the retina called the *identical points*, and which are situated almost quite symmetrically in both eyes. As soon as this relation is disturbed, double-sight is the consequcnce. But even in looking quite normally, we often see objects double unless we fix our eyes; because they do not fall on the identical spots in the retina. For example, hold your finger close before your eyes, and fix your gaze on a distant object, and you will have a distinct twofold image of the finger. But the attention is so concentrated on the objects on which we fix our eye, that we are little aware of this double vision of the object looked at indirectly.

And now what is the primary object to be gained by

this seeing double? Is the use of a second eye allowed us, solely to provide us with greater security for the preservation of our sight, and a wider range of vision; or is it simply to be looked opon us a result of the symmetrical adjustment of our body? No, it springs from a connection which more deeply affects the perceptions. A perspective image of the exterior world being projected as we know, on each retina, can for the first only reach our consciousness. Although we can perceive the objects bodily also with one eye,— apart from our conceptions gained by experience, — this is owing to our perceiving with every change in the position of our head, or of our point of view, a new perspective picture of the same object, by the nearer shifting in the direction of the more distant. Looking with one eye, awakes the impression of *depth* or *solidity*, but only from the constant *changing of the point of view.* A one-eyed man, to use the words of a celebrated physiologist, as long as he sits still, sees not the world itself, only a perspective image of it. The case is quite different, when we look with two eyes. From each as from two different points of view, we get for each eye another perspective picture. Hold your finger up at some distance from your face, and if you close your right eye, you will perceive that the finger covers other spots of the distant objects than when you close the left eye and look with the right; and this will be the case with all objects at various distances.

Four hundred years ago Leonardo da Vinci* called attention to the fact, that by the use of two eyes more of the objects behind any given body were visible, than with one eye;

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* Tractat von der Malerey, übers. von Georg Böhm. Nürnberg, 1724. P. 91 and 92.

for in the former case the scattered impression of both eyes were combined. He complained also, that the art of painting was unable to imitate this advantage, which mostly exhibits the object as *raised*, or standing out from the surface. It was reserved for the English physician Wheatstone in our own times, to comprehend this fact in all its bearings, and to construct that instrument which furnishes a common source of amusement, and is likewise a main aid in scientific experiments. When we slip two different perspective views of a body as seen by the right and left eyes, into the *stereoscope*, whose fields of view are equally divided for both eyes, — there is painted on both retinas the same two pictures, impressing us as if we beheld the bodily object itself; and as we usually receive the impression of both images on our retina under similar circumstances, we believe in the actual presence of a solid body even under the above artificially-produced condition. That which we can attain for only *one* eye, by a succession of changes in the point of view, I mean, the perception of depth, we can get for two eyes in less than a second, by the combination of both views; and from the very fact of its taking place in a second, the two points of view of both our eyes being in ourselves,— the impression of the solid, which we owe to our two-eyed vision, is comparatively more lively and direct.

So much then on the organ which for the nourishment of our mind, for the relation of man to man, and for the rectifying and confirming of our views of the world, exercises such an influence, on the extent of which he who is still in the undiminished possession of it, can indeed scarce render account. Orators have lauded it, poets sung it; but its full value

is only to be found in the mute depths of the yearning of those who have had, and possess it no longer.

From another peculiar point of view, natural philosophers are justified in calling it the jewel of the Creation. From the richness of its manifold structure, the lavishness of the most perfect expedients with which its high aims and objects are attained, and from the crystalline clearness of its parts, which allows of a deeper insight into its conformation than into any other of our bodily organs, it has become a test of medical thought and a treasury of *study for the natural philosopher.*

Yes; those are the studies which closely allied with each other, concentrate their efforts on the one common aim, that of discovering the *one* great power in nature; the one *power* that rules and holds together all natural appearances according to the same immutable laws,—be it to stir the ocean in its depths, or to dispose the molecules in their organic cells; be it to hold the celestial bodies in their appointed paths, or to guide the tiny æther-wave on its shining path to our retina. There is nothing perishable in this power; its laws are undecaying, and we too, though trammelled by human frailties and caprice, are impelled by a higher spirit when we fix our thoughts, our desires, our unquenchable thirst after knowledge, on the works of Nature, which are needful as they are undecaying. Let a haughty intellectualism if it will, accuse natural science of a blameworthy materialism; such accusations will but spur her on to become more and more conscious of her ideal vocation, viz., to enquire the Eternal Will of the Creator at every spring of existence; and enriched with divine truth, to become a teacher and dispenser of true humanity.

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