Dissertation

on Accommodation of the Eye

Auctore Wm. Henry Symes 1836.  
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Author's Copy.
(1). Before entering upon the subject proper of my Dissertation, I beg leave to offer a few remarks on the sensory functions.
Mr President and Gentlemen (1)

The Sensory System (2) includes the functions by which we are made conscious of external agencies.

Johannes Müller says (Vol. 17, p. 1065)

"Sensation consists in the sensorium receiving through the medium of the nerves, and as the result of the action of an external cause, a knowledge of certain qualities or conditions, not of external bodies, but of the nerves of which themselves, and these qualities of the nerves of sense are in all different; the nerve of each sense having its own peculiar quality or stimulus."

I think we must distinguish between the act of sensation itself, and the impression and perception which accompany it - the action of the outer world upon the living sensory organ constitutes an Impres-
(1) It is asserted by some, but not yet fully established, that the Pulmo-gastropoda possess organs of vision in connection with their tentacles or feelers. Huskley, however, in his recent volume on Comparative Anatomy, states that this class, as well as the Brancii gastropoda and Pleopoda, possess rudimentary organs of vision.
The subsequent reaction of the sensory organ constitutes sensation. The mental process induced by sensation constitutes perception.

We find no trace of a special sensory system in any of the classes included in Cuvier's Raritäten, nor in the lowest of those of the Mollusca; for all the functions possessed by these classes belong to the Nutritive, Generative and Motory systems. But come the Lamellibranchiata, Gasteropoda + Pelecypoda, with their so-called Central ganglion of doubtful significance (1). Last by however the highest class of the Mollusca, the Cephalopoda, present well defined organs of vision, besides indication of an olfactory and auditory system.

Of all the senses enjoyed by man, that of vision is the most important, whether we view it in reference to the extent of its range, the value of its results, or the structure of its organs. With the sense of Touch and Taste we are brought into immediate contact with the objects of our examination. With the organ of
smell, we inhale from a short distance the radiating or the floating effluvia. The sound of the troubled sea, or of the gale which disturbs it, or of the thunder which rolls above, is heard from afar. But the Eye carries us to the remotest horizon around, glances upward beyond the still air, through the planetary regions where worlds are but stars, through the diurnal zones where suns are too small to be seen, and where Imagination and Reason are alike baffled. Vision still maintains her precedence in the study of the organizations of the microscope world, the forms and functions of atomic life, or the larger structures of the creatures around us.

As regards the relation of our senses to our moral being, some maintain that Hearing, as the medium of social intercourse and of the influences of Music, is a greater boon to our race. But I consider that Vision appeals to our judgment and Imagination, which are the highest of man's
moral attributes, while hearing appeals to our impulses and sentiments (or affections) which are moral attributes of a lower standard.

It is a very curious fact in connection with vision, that very distant objects are visible to us, long after they have ceased to exist. Thus, if a fixed star is destroyed, or cease to give light, it will according to its distance, continue visible for years, or for centuries, the arrival of the last ray projected from it at length conveys to our eye the fact of its disappearance, or of the extinction of its light. Nor are the powers of observation dependent on the magnitude of the eye-ball, or of any of its parts. The minutest eye of the minutest animal, which itself requires a microscope to make it visible, has painted upon its retina a representation of the external world, as distinct and as large, when transferred outwardly by the laws of vision, as that which is seen by the eye of the elephant or of the whale. In addition to these intrinsic qualities, the human eye is admirable as a work
of art, for the beauty of its form, the range and quickness of its movements, and the variety of its expression.

Perfect vision involves two conditions: the first is optical, and consists in the formation of an inverted, well-defined, image of the object on the Membrana fakobii, or layer of rods and bulbs of the retina.

The second condition is nervous, and consists in the local change excited in Jacob's membrane being conveyed to the fibres of the optic nerve through the interweaving fibro-granular layers, and transmitted by these to the brain, where the act of sensation is completed, and the act of perception accomplished, in a manner very uncertainly known.

It is believed by many that the peculiar stimuli transmitted to the brain by the optic nerves is again projected outwards in an inverted direction, so that what the eye sees is not the object itself, but its virtual image, reprojected from the retina. This theory explains very well why
(1) I consider that the study of every function should be divided as follows:

1. Physiology, or general nature of it.

2. {Anatomy, } Comparative

Mechanism

Thus, in the case of vision, I would consider in the first place its physiology, or the general nature of its phenomena; and then the anatomy and mechanism of its organ in the various classes of animals, commencing with the lowest, and tracing its development upwards. I would not carry my division of subjects beyond the primary function, as enumerated on page 1; that is, Digestion, Circulation, Respiration, etc. Then vision, etc. In the present case, we have to consider only a secondary or subordinate function. To commence then with the physiology of accommodation; I define it as the function by which re-
we see objects in their proper erect position, and not in the inverted position of the retinal image.

Such being the conditions of perfect vision, I classify the functions as follows:

A. Optical Functions
   1. Direction (of the axis of vision towards objects)
   2. Refractions (of the rays from the object to a focus upon the retina)
   3. Accommodation (of the refracting media to distance).

B. Nervous Functions
   1. Reception (of the image by the retina)
   2. Transmission (of the retinal stimulus to the brain)
   3. Sensations (of the effect of the preceding impression upon the Sensory Ganglia at the base of the brain).

The function of Accommodation is the one which I wish to consider more especially at present (1).

Accommodation of the Eye is the function by which the refractive media of are enabled to bring divergent rays
to a focus upon the retina.

The refractive media of the eye, when the organ is in a state of rest, are in fact only able to bring only parallel rays to a focus upon the retina; and in this respect their object might be equally well attained by a one-inch convex glass lens.

The properties of convex lenses, and of the refractive media of the eye, ought to be considered at length as a separate subject, but it is here advisable to say a few words about them.

The chief property of convex lenses is that of converging, or drawing together the rays of light by which impinge on them. Thus, rays originally parallel, such as those derived from distant objects, are made to meet at a point called the principal focus. Rays, originally divergent, such as those derived from near objects, are made to meet at a point further from the lens than the principal focus. Lastly, rays, originally convergent, are focussed at a point nearer to the lens than the principal focus. All lenses are named accord.
...ing to their focal length; this a one-
-inch convex lens, means one which will
focus parallel rays at the distance of
one inch; or conversely, which will render
parallel rays diverging from a luminous
point one inch distant.

If now we turn from the consideration
of glass lenses, unchangeable in their degree
of curvature, to the soft media which
perform an analogous function in the
eye, but which by their pliability are
so easily modified in their degree of curva-
ture, we cannot but be struck with the
superiority of the work of nature to that
of human art.

The human eye-ball is described by
some anatomists as being a true sphere,
but by the greater number as being a
spheroid, the antero-posterior diameter
of which is greater than any other. This
Petit described the proportion of the
antero-posterior to the transverse diam-
eter as 5:10 to 13:5; Sommering as 10 to
9:7. Rumley of Leeds & others have
however proved by a great number of
laboriously executed measurements, that while the posterior part of the human
sclerotic is probably under all circumstances perfectly spherical, the anterior
part of it and the convexity of the cornea vary to some extent in different subjects,
and even in the same individual at different times, but that in all cases, both
in man and the lower animals, where there is any departure from sphericity, the
largest diameter is found to be the transverse, and not the antero-posterior.
The average antero-posterior diameter of
the eye, measured from the vertex of the
cornea to the diametrically opposite
point of the outer surface of the sclerotic
is 24.25 millimetres, or as expressed in
English inches 0.9547.

The refracting system in this globe con-
ists of a number of transparent media,
differing in their refractive power, and
separated at various intervals by surfa
ces of different degrees of curvature. The
media are four in number: the substance
of the cornea, the aqueous humour, the
1. "Dioptric" is derived from διόπτρικος, from διόπτρα = to see through, from δι = through, + ὀπτήρα = to see. It is sometimes written dioptric, dioptical, diaoptical. (Harris)

2. Explain axis of vision, eccentric position of the optic nerve etc.
substance of the lens, and the vitreous humour. The curved surfaces are considered to be only three: the anterior surface of the cornea, the anterior surface of the lens, and the posterior surface of the lens. You will remark that the posterior surface of the cornea is not here taken into account; the reason being that its index of refraction scarcely differs from that of the aqueous humour. These media or surfaces constitute what is termed the dioptic system of the eye (1). The axis of vision passes through the optical centre of this eye system, and terminates at the focus centralis, or centre of the yellow spot of the retina (2).

In the normal eye the retina is placed precisely at the focus of this dioptic system, and it is the object of accommodation to preserve the constancy of this important relation. Thus, if we carefully cut away the sclerotic or choroid in a sheep's eye, or if we isolate an albino eye without any further preparation, and if we then look through the transparent retina at any distant object,
we perceive a distinct inverted image of the object figured accurately upon the
sheep's retina. If, however, we look through
the same prepared eye at any near
object, all we perceive is a confused, or
blurred figure, such as all of us are
familiar with when we look through a
microscope slightly out of focus. The
reason is clear enough: the rays from
the distant object are parallel, and are
focussed exactly upon the retina of
the prepared eye; while the rays from
the near object are divergent and con-
sequently produce only circles of diffr-
action on that retina. A similar expe-
rience on the living eye may readily be
performed, by asking another person
to look steadily at a distant object;
when, with an ophthalmoscope, we may
see upon the fundus of his eye the diffuse
image of any near object occurring in
the line of vision. But in our own
eyes we all know that we are able
to see near objects as well as distant
ones, which means that we can focus
divergent as well as parallel rays. This power which all normal eyes enjoy is termed the faculty of accommodation.

Any one may observe the occurrence of, and thus occupied by, this act of accommodation, if, while standing at a window, he looks first at an object the other side of the street or still farther off, and then suddenly at the glass of the window itself. Besides perceiving a change in his eye, the observer will remark that it is impossible to see at one and the same moment the object in the distance and the glass intervening. The time required for accommodation varies. In most kinds of sport, accuracy and rapidity of accommodation are very essential. Thus, in (riffl) target practice, accuracy of accommodation is the great essential desideratum; in partridge shooting, rapidity of accommodation is more essential; while in cricket both qualities are indispensable. It has been remarked that most of the All-England cricketers have blue eyes; our Australian Cousins first
draw attention to this feature, in the case of the twelve who went out there in 1865, of whom presented it. What however the connection may be between accommodation and the deposition of pigment in the iris, I am unable to say.

What change occurs in the Dioptric system of the eye in Accommodation?

Various changes have been suggested, of which the principle are: alteration of form and position of the lens, elongation of the axis of vision, contraction of the pupil.

About the commencement of the present century, the hypothesis of a change of form in the lens received considerable support from experiments by Thomas Young; but it was not till 1849, that this theory received direct proofs. These were obtained by the reflection of images by the anterior and posterior surface of the lens. These images were discovered by Pinchvee in 1823, and were applied by Lauthon to the Diagnosis of Cataract in 1837. Lauthon was the first to investigate these images with reference to the important question of
accommodation, but Ramon and subse-
quently Helmholtz have the chief honour
of establishing almost beyond doubt
the existing theory of accommodation.
The observation of these reflected images
proves distinctly two things: firstly that
both surfaces of the lens increase in curv-
iture; secondly, that the anterior surface
of the lens advances nearer to the cornea.
These observations cannot be understood
without a previous knowledge of the pro-
erties of convex and concave mirrors: how
the former give an erect image behind
their reflecting surface; how the latter
give an inverted image before in front
of their reflecting surface; and how in
both cases, the size of the image dimin-
ishes in proportion to the curvature of
the mirror. This may be very aptly
illustrated by holding a pocket lens
towards a flame, gas-light or window.
Firstly, one remarks the large erect image
of the fire, flaring upwards, which is
reflected from the anterior convex surface
of the pocket lens; secondly, the smaller
inverted, and much less distinct image of the fire, flaring downwards, which is reflected from the concave surface of the air in contact with the posterior concave surface of the lens; thirdly, one remarks that the different powers of the pocket lens give larger or smaller images in proportion as they are less or more concave.

Cramer applied this principle to the crystalline lens, and found, that when the eye passes from a state of relaxation to a state of accommodation for near objects, the erect image reflected from the anterior surface of the lens becomes considerably smaller, while the visual angle between it and the reflected image of the cornea also diminishes. Thence he correctly inferred that the anterior surface of the lens becomes more concave and approaches the cornea. The honour of investigating the image reflected from the posterior surface of the lens, or rather from the contiguous concave surface of the vitreous humour, belongs to Helmholtz, who proved that it diminishes...
(1) V. Treatise on Physiological Optics, by J. Helmholtz in Rahsteus' Allgemeine Encyclopädie der Physik, Leipzig 1856-60.

ishes slightly, but does not perceptibly change its position. Helmholtz has also the merit of establishing by profound mathematical investigations the accuracy of these optical phenomena. Helmholtz concludes by saying:

"The changes which I have observed in the dioptric system of the eye during its accommodation for near objects are the following:

1. The anterior surface of the lens becomes more convex, and its vertex passes more forwards.
2. The posterior surface of the lens becomes slightly more convex, but does not perceptibly change its position. The middle of the lens therefore becomes thicker.

Besides these primary dioptric changes, I have observed the following changes in the iris:

1. The pupil contracts.
2. The pupillary margin of the iris advances forwards.
3. The periphery of the iris is thrown
backwards."

From these conclusions of Helmholtz, it is evident that the lens is the essential organ of accommodation. The lens might indeed be easily dispensed with for all other purposes of vision, since, after its removal for cataract, etc., often the only serious defect of vision is the loss of accommodation. I must however state that various authors, especially Arlt, Hone, Memoir, Tou Carion, and even Gräfe, have asserted that accommodation is not entirely lost after extraction of the lens, but Donders has vindicated the accuracy of Young's theory, by proving that what has been mistaken for accommodation by these writers is merely the effect of contraction of the iris in diminishing the circle of diffusion. Before concluding my account of these changes in the optic system, I would remark how curiously the old hypotheses, which successively prevailed and were as successively rejected, have finally been all embodied in the existing theory. Thus, since Kepler's time till 1849, the opin-
...ions which have been by turn in vogue are: 1°. Alteration of the lens; 2°. Elongation of the antero-posterior diameter of the eye; 3°. Contraction of the pupil; 4°. Change in the form of the lens.

Anatomy and Mechanism of Accommodation in Man.

We have now to examine by what agency the form of the lens is changed; in other words, what is the Anatomy and Mechanism of the organ of accommodation.

The first step towards the solution of this problem lies in the easily recognized fact that accommodation is produced voluntarily, and voluntary movement implies the intervention of muscular elements.

Where then is this muscle, or system of muscles, to be found? John Hunter, Young, and other physiologists of the last century thought the fibers of the crystalline lens were muscular, and hence named it the 'musculus crystallinus'. It has however been galvanized with but negative results.

In the next place, we find Le Camus, Rohault, Schröder van der Kolk, and Arlt-
advocating the agency of the extrinsic muscles of the eye, the recti and obliques, producing accommodation by elongating the axis of the globe. This hypothesis is completely refuted by a case recorded by Gräfe in the Archiv. f. Ophthalmol., Vol. vii., where paralysis of all the recti and obliques did not affect the accommodation. The convergence of our eyes by the internal recti, when we look at near objects, is merely a concomitant of the accompanying accommodation. Since, therefore, the external muscles of the eye have no direct influence on accommodation, we must seek for our muscular elements exclusively in the eye. The only muscular element known to exist inside the eye-ball are the iris and ciliary muscles. In the eye of the Mammalia these are composed of unstriped muscular fibre; but, in the eye of birds, the latter is replaced by striped muscular fibre, we are warranted in assuming that the same voluntary control exists in each case, though probably to a greater extent...
in the case of birds. Indeed, it is as little strange that unstriped fibre should here be subject to the influence of that the striped fibre of the heart should be withdrawn from it.

I shall now conclude by giving you a short and concise description of the arrangement and ciliary system in connection with the diagrams.

No very definite opinion is as yet entertained about the mechanism of accommodation, but I think the following is the most probable:

1. When the eye is at rest, it is adapted for vision of quite distant objects (21); the internal muscular system is relaxed, but the lens is flattened by tension of its ligament, through the vitreous humour.

2. When the eye is accommodated for near objects, the pupil contracts, and the ciliary muscles relax, the ligament of the lens, which therefore assumes a greater convexity in virtue of its elasticity.

W.H.