STRUCTURE AND FUNCTION OF CEREBRAL COMMISSURES

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Edited by

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PREFACE

The present book contains a collection of papers culled from the European Brain Behaviour Society's Workshop on *The Structure and Function of the Cerebral Commissures*, which was held at the Erasmus University Medical School from March 30 to April 2, 1977. The meeting was supported by the Gerrit Jan Mulder Stichting, Rotterdam. Funds were also generously donated by: the European Brain Behaviour Society; the Erasmus University; the Fonds Medische Faculteit Rotterdam; Blydorp Zoo, Rotterdam; Ciba-Geigy; Heineken Breweries; Nefarma; Organon; Unilever and Union Chimique Belge. Both the editors and the contributors wish to express their appreciation to these organisations for making the Workshop possible.

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INTRODUCTION TO THE BEGINNINGS OF COMMISSURE RESEARCH

G. ATAL RUSSELL and I. STEELE RUSSELL

The origins of the work on interhemispheric relations arise from partly philosophical and partly medical concerns with the explanation of the unity of perception or consciousness. As such the various theories and speculations have essentially focused on two principal structures in the brain. In the periphery the optic chiasma was early considered as a mechanism of visual integration. The unity of consciousness was believed to be a product of central integration which was originally thought to occur in the ventricular system; and much later this function was assigned to the commissures.

The earliest written description of the optic chiasma and its connections with the brain in fish was provided by Aristotle (384–322 B.C.). Believing that the brain was little more than an accessory to the heart, he attached no particular significance to the chiasma. Herophilus (fl. c. 300 B.C.) and Erasistratus (fl. c. 260 B.C.), the pioneers of the Alexandrian school of anatomy and medicine, correctly identified the visual role of the optic chiasma. The optic nerves, believed to be hollow tubes were described in Rufus of Ephesus (fl. c. A.D. 98–117) as emerging from the base of the brain and meeting in the chiasma, and then bifurcating laterally to enter both eyes. Aretaeus, the Cappadocian (c. A.D. 81–138 or c. 131–200) described them, however, as completely decussated in the form of the letter χ .

The influence of Galen (A.D. 129–199) in physiology and anatomy, and in particular concerning brain function was a watershed in science. His treatment and interpretation of the visual system were the first attempt to provide a coherent mechanistic explanation of visual perception in anatomical terms. Morphologically he regarded each optic tract not as nerves but as tubular extensions of the brain itself, originating from the lateral ventricles which he termed *thalami* or cavities. The optic nerves were considered to extend from the brain separately, to come together without any decussation, and to end inside the eyes. There each nerve thins out to form the retina (*arachnoeides hitôn*) which extends as far as the lens (*krystalloeides hitôn*).

The function of this system was to provide a hydraulic exchange circuit in the eye to permit the transfer of information from the environment to the brain. Galen believed the ventricles contained a *luminous air* (*pneuma horatikon*) which circulated via the channels of the optic nerves to the eye, and from there to the outside where, in the presence of light, it altered or 'stressed' the surrounding air.

The impression of the object to be perceived was then transmitted to the eye by this 'stressed' air in the form of the Euclidian cone with its base on the object and its apex at the pupil. The two were connected by 'visual rays' which were to be thought of as straight lines analogous to a multitude of fine gossamer threads. Galen regarded the lens as the principal organ of vision or the structure where photoreception occurred. Its alleged function was to act as an exchange membrane where the pneuma could be 'charged' with the images located there by the visual rays (*opseis*). Visual perception was completed only when the pneuma conveyed these images back to the brain, which was the ultimate site of consciousness. Without the transfer of information by the lens, vision would not be possible.

Galen's views on the optic chiasma were also obscure. Its principal function was to ensure a proper distribution of pneuma from the brain to both eyes. During monocular vision it acted to redeploy all of the available pneuma to the open eye, thus to compensate for the loss of one receptor by doubling the power of the other. At the same time the chiasma served to prevent diplopia.

Further developments in our understanding of the function of the optic chiasma had to wait until the early beginnings of modern physiology and the rise of experimental scientific enquiry. This began with the recognition of the eye as an optic instrument in Islamic science. A significant feature of Arabic treatises and books on medicine and physics is their detailed description of the structure and function of the eye. What is perhaps more important is the fact that for the first time in history they use detailed illustrations of the eye, optic nerves, and the brain. For example, Hunain ibn Ishāq (Johannitius, A.D. 809-877) produced a diagram of the eye (see figure I.1) that was not only remarkable for its detail and clarity, but represents a genre that powerfully influenced all early European diagrams of the eye by Roger Bacon, Pecham, Witello, and even da Vinci and Vesalius. Such early Arab physicians as ibn Ishāq were, however, adherents of the emanation doctrines as well as being assiduous practitioners of Galenic principles.

The most comprehensive and systematic alternative to classical optical theories was formulated by the mathematician-physicist Ibn al-Haytham (Alhazen, A.D. 965-1039) who had a profound influence on Western science. His principal work on optics (*Kitab al-Manāẓir*) was already translated into Latin by the thirteenth century and together with Risner's printed edition, *Opticae thesaurus* (1572) dominated European thought until the seventeenth century. It is for this reason that he is known as the father of ophthalmology.

The essential feature of Ibn al-Haytham's system is his theory of direct vision and his uncompromising rejection of emanation theory. His statement that 'the act of vision is accomplished by means of light rays coming from external objects and entering the eye . . . and the belief of those who think that something comes out of the eye is false' is both trenchant and clear. Of paramount importance was his belief that an unqualified reliance on naive sensory observation was inherently undesirable. He gives as an example of this the illusion of seeing the moon move when it is observed in the wake of morning clouds. True scientific knowledge, Ibn al-Haytham insisted, could only come from anchoring all observations to

vision and to induce pain, which indicated to Ibn al-Haytham that vision could only result from light rays entering the eye from the outside world. The emission of the eye's own rays could not be responsible for the experience of pain. Similarly he argued that the phenomenon of visual after-images was due to the external bright light producing a temporary injury to the eye.

In optics he made significant contributions to both catoptrics and dioptrics. Not only did he experimentally confirm the first law of reflection, but he was responsible for the second law that the incident, normal and reflected rays always lie in the same plane. His major contribution was, however, his experimental studies of light refraction. He was the formulator of the first law of refraction and part-discoverer of the second law. By careful and systematic observation he established the fact that the angle of incidence is always greater than the angle of refraction. Further, he noted that when the angle of incidence is less than 20° the ratio of the two angles is constant. For angles of incidence greater than this the ratio was variable. Despite his familiarity with trigonometric tables he did not compare the sines of the angles, and thus left the complete formulation of the second law of refraction to Snell to complete in 1621. Ibn al-Haytham was mainly limited in studies of dioptrics to considering the refraction of light from air to water. However, preliminary observations on the refraction of light by water-filled glass bottles led him to explore the mathematical properties of magnifying lenses, which due to the inadequacies of the technology of his day were not taken further. Finally he performed numerous experiments with the pin-hole camera, where he first demonstrated how the image of an external candle was inverted on the screen inside the chamber.

In his treatment of the eye Ibn al-Haytham for the first time gave us the modern synthesis of anatomy and physical optics. His description of the structure and mechanisms of the eye is a model of clarity and attention to detail, suggesting that his knowledge of the anatomy of the eye came from dissection and detailed observation. In particular his exact description of the lens illustrates this point. To Ibn al-Haytham the round shape of the lens with its biconvex lateral appearance resembled a lentil grain. He further noted that the anterior surface of the lens was relatively flat compared with the posterior surface which has a much shorter radius of curvature. The Arabic word *adasa* (lentil) was translated into Latin as *lenticula* which is the origin of the English word lens. Another example of the early diffusion of Arabic influences to the West is seen with the word cornea. The transparent anterior surface of the eye was called *al-qarniyya* in Arabic to refer to a protrusion or horn. This was conveyed directly into Latin as cornea with no attempt being made to translate it.

Ibn al-Haytham likened the eye to a modified 'dark chamber' or pin-hole camera, where the pupil acts as an aperture to project an upright image on the back of the posterior chamber of the eye. Despite his pioneering investigations into refraction he totally failed to appreciate the true function of the lens. Instead he believed it was that part of the eye where visual sensations are first experienced as is the case when intense light induces pain. Light rays were refracted by the vitreous humour in such a way as to form an upright image. This image was created by the perpendicular light rays from the object to the eye so that each point of

the object has a corresponding spatially organised point on the retinal image. This image or pattern of stimulation was thought to be preserved as it travelled in the hollow optic nerve to the brain where conscious perception of the object occurred. These ideas of Ibn al-Haytham clearly represent one of the earliest formulations of the concept of topographic retinal projection to the cerebrum.

Furthermore this notion of retinal information having a punctate organisation in the optic nerve was a cardinal assumption in his explanation of both the unity of perception and the function of the optic chiasma (see figure I.2). He believed the chiasma to be an association nerve (al-asaba al-jawfa al-mushtarika) where the contents of the two optic nerves came together and were mixed. This enabled the separate images from the two eyes to be superimposed and establish an exact match to generate a single fused image which in turn was conveyed to the brain resulting in a single visual experience.

An alternative view of the chiasma was provided by ibn Sina (Avicenna, A.D.

Figure I.2. Drawing adapted from a diagram of the visual system from the oldest copy of the *Kitab al-manazir* by Ibn al-Haytham. Manuscript dated A.D. 1083 in the possession of the Fatih Library, Istanbul. For identification of parts represented see Figure 8, p. 41 in S. Polyak, *The Retina*

980-1037) the great savant from Bukhara in Turkistan. In contrast to Ibn al-Haytham he believed the optic nerves in the chiasma to be completely crossed (see figure I.3) such that the separate images from the eyes are conveyed to opposite lateral ventricles. He provided the answer to the problem of the unity of consciousness by having the third and fourth ventricles act as association chambers to unite the separate images.

Thus by the end of the eleventh century both a peripheral and a central theory of the unity of consciousness had been promulgated in terms that were to remain

Figure I.3. Diagram of the visual system from a manuscript by Khalifa c A.D. 1266. The upper part shows the two lateral ventricles, with the third and fourth ventricles of the brain in the midline. The complete crossing of the optic nerves in the chiasma is shown. See S. Polvak. *The Vertebrate Visual System*

essentially unchanged for the next 600 years. It was not until Descartes published his *Traité de l'Homme* in 1686 that a neural alternative was proposed to the ventricular hydraulic model. With the advantages of the new knowledge in optics and mathematics Descartes was able to reformulate Ibn al-Haytham's ideas of projection in modern form. The pineal gland then became the neural site where binocular integration occurred during vision. It was not until 1903 that the central integrating role of the corpus callosum was discovered (Imamamura, 1903).

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