

Vignette 2.1

The Medieval Eye

SHIPS THAT DOCKED IN THE ANCIENT CITY of Alexandria, Egypt, were routinely searched for manuscripts to be copied or confiscated as additions to the Alexandrian library, which was meant to contain every book ever written. This goal was probably never achieved, but the library's collection has been estimated at almost a million papyrus scrolls (books in those days), and many of them were the sole copy. The final demise of the library of Alexandria around A.D. 500 was a loss of incalculable magnitude; our intellectual heritage was decimated.

Part of the loss may have been *The Book of the Eye*, a text written by Herophilus (circa 335–circa 280 B.C.), who was regarded as the greatest of the Greek anatomists. Its existence is inferred from other writings that survived. From other authors who seem to have seen such a book, we know that Herophilus understood and described the anatomy of the eye in some detail and that he discovered and described the nerves of the eye, among other things. Some contemporary scholars believe that Herophilus used illustrations in his book, which makes its loss all the greater; they would have been the first known anatomical illustrations of the eye. More important still, Herophilus would have been writing about things he had observed; he dissected the human body and was one of the last to do so for nearly 15 centuries. (The possibility, hotly debated, that Herophilus sometimes practiced human vivisection is too appalling to contemplate for long.)

Much of what we know about the work of Herophilus and other Greek anatomists comes from the writings of Galen (A.D. 129–circa 199), who was the principal inheritor and exponent of the knowledge acquired by the Greek philosophers. (All fields of intellectual inquiry, including what we now call science, were philosophy as far as the ancients were concerned.) Galen was extremely well educated, widely read in the classical literature, extensively traveled, and the dominant figure in anatomy and medicine until the Renaissance. His enormous influence came from his erudition, his strongly held opinions, his skill as a polemicist, and the enormous volume of his writings (then, and later, he was referred to as a “windbag”).

Because human dissection was not permitted in Galen's time, his detailed descriptions of ocular dissections refer primarily to bovine and simian eyes. He was thoroughly familiar with the work of Herophilus, however, and whatever preconceptions Galen had about the structure of the human eye probably derived from this source. In any event, he was certainly influenced by the earlier Greek writers on vision and the function of the eye, and it was their ideas about vision, expressed in Galen's words, that was to influence thinking about the eye for almost a millennium. (Vignette 3.2 has more to say about Galen's influence.)

If we did not have some idea about the structure of the eye, it would be difficult to reconstruct from Galen's description; there are no pictures, the meanings of words are obscure, and translators do not always agree about Galen's terminology, as they point out in extensive footnotes. But some essential features are clear: Galen understood the three-layered structure of the eye, the relationship

of the retina to the optic nerve, the difference between the aqueous and vitreous chambers, and the existence of oculorotary muscles (although he assumed that humans also have a retractor bulbi muscle like that of some other animals). It is also clear that Galen viewed the lens as the seat of vision.

The first illustration of Galen's ideas, or at least the first we know of, was done by an Arab physician, Hunain ibn Ishak, in the latter part of the ninth century A.D. This representation of the eye (Figure 1) is highly symbolic, but some of the key structural features of the eye are present and consistent with Galen's descriptions. The eye has three major coats—the sclera and cornea, the choroid, and the retina in our terms—with a thin outer layer that could correspond to the episclera and Tenon's capsule (see Chapter 3). The drawing includes a lens, the fluid-filled aqueous and vitreous chambers, a pupil, and an optic nerve. But while the major elements are present, their sizes, shapes, and positions differ from our modern version. The optic nerve, for example, exits at the posterior pole and runs straight back from the eye, instead of running medially, and the lens is depicted as a sphere located in the center of the eye. And just in front of the lens is a structure with no anatomical counterpart; it represents the visual spirit and reveals the drawing's Greek inspiration.

Vision was the most difficult sense for the ancients to understand. While the wind on one's face offered clues to the nature of sound and its medium of transmission over long distances, there were no comparable hints about light. What it was, how it was transmitted, and how it might interact with the eye were mysteries about which one could only try to deduce solutions. Plato and his followers, who influenced Galen, treated vision as a sense analogous

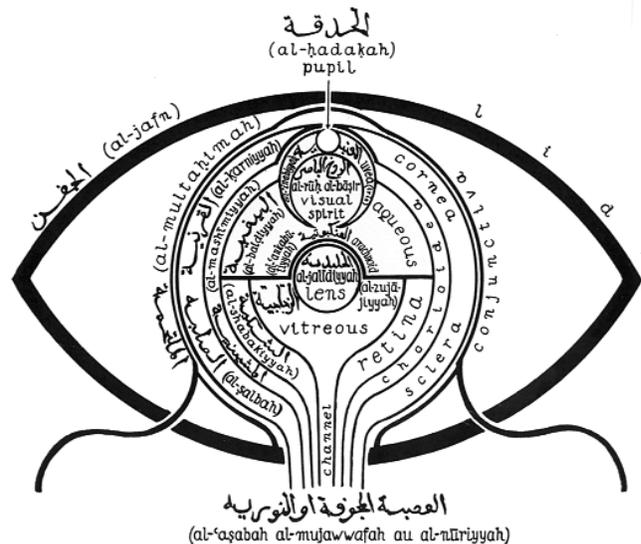


Figure 1
The Human Eye a Thousand Years Ago

A cross section through the eye is shown framed by the aperture of the lids as viewed from the front. Note the central, spherical lens, the hollow optic nerve that is continuous with the vitreous chamber, and the structure representing the “visual spirit” just in front of the lens. (From Polyak 1941.)

to touch; it was as if rigid, invisible rays of a vital spirit emanated from the eye and vibrated when they encountered an external object. (Plato’s student Aristotle disagreed and believed that light, whatever it was, came from objects to the eye.) They believed that the vibrations were concentrated by the lens—hence its central location—and transmitted to the brain by fluid in the eye and the optic nerve. Thus, the visual spirit in this drawing is the source of the emanating rays through which the eye sensed the environment.

The drawing in Figure 2 was done a century later, around A.D. 1000, and it marks an immense change in thinking about the eye; there is no longer any representation of a visual spirit. This drawing was done by the great mathematician Ibn Al-Haytham (965–1039), generally known by the Latin version of his name, Alhazen. Like Euclid before him, Alhazen had a geometer’s love for optics, and his investigations convinced him that rays of light enter the eye from external objects, not the other way around. (Alhazen neither knew nor cared about the nature of light, which made much of the philosophers’ considerations irrelevant.) By eliminating the visual spirit, Alhazen demysticized the eye, making its operation subject to the same optical principles as any glass lens. Where the eye was once a matter of wonder and speculation, he made the eye an object that could be studied and possibly understood.

Alhazen’s drawing is not explicit about anatomical structure, but he shows the optically important proportions and curvatures of the cornea and sclera quite accurately. His major failing is the lens; he placed it more nearly in its correct location than Ibn Ishak had, but it is still depicted as a large circle, presumably a cross section of a sphere. (Note that the pupil, represented by the small circle at the front of the lens, and the optic nerve head, the circle at the back of the lens, are drawn as they would be seen when viewed from the front of the eye; they have been rotated 90° relative to the plane of the main drawing. This stylistic representation of features in their most characteristic aspect, with different vantage points for different features, is quite ancient; it is particularly obvious in Egyptian art. Thus the large circle representing the lens may also be a frontal view.)

Alhazen understood image formation in terms of the camera obscura (pinhole camera), and his drawing suggests that he believed the image to be formed at the back surface of the lens. (The quantitative law of refraction was first derived by the Dutch astronomer and mathematician Willebrord Snell about 600 years later.) This location is wrong, but it is consistent with the powerful spherical lens that his drawing may be indicating, and it places the emphasis where it should be—on the image-forming properties of the eye. The ocular image would interact with the optic nerve, which Alhazen shows running from the back of the lens to the point at which it joins the nerve from the other eye at the optic chiasm. (The representation

of the optic chiasm is also unprecedented.) Alhazen’s depiction of the optic nerve within the eye is incorrect, but it is consistent with the prevailing view of the optic nerve as the sensory element of the eye. Because of its obvious blood vessels, the retina was thought to be mainly nutritive in function (Galen again).

In the late medieval period, Alhazen’s work was translated into Latin and became the basis of several thirteenth-century treatises on optics, including the *Opus Majus* of Roger Bacon (circa 1220–1292), the *Perspectiva Communis* of John Pecham (circa 1230–1292), and the *Perspectiva* of Witelo (or Vitellio; circa 1230 or 1235–after 1275), all of which included diagrams dealing with the optics of the eye. The importance of these works is not that they added much new, but that they were excellent syntheses and brought optical knowledge to a much wider audience. Bacon and Pecham hedged on Alhazen’s dismissal of the visual spirit, but Witelo adopted Alhazen’s position unreservedly, and this was the view that was to influence the scholars who made the next major advances. But those advances had to await the Renaissance.

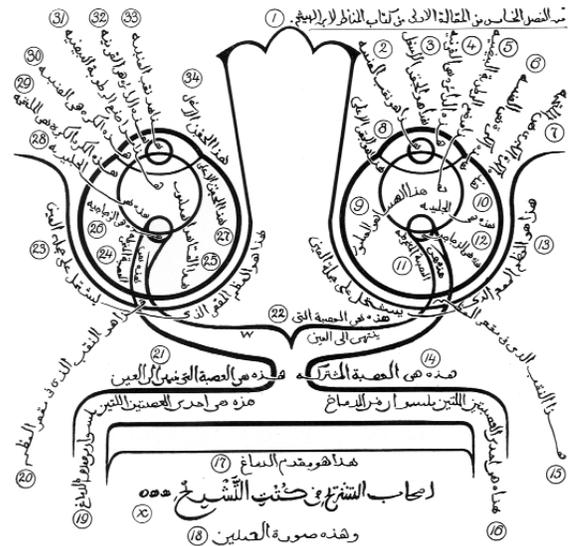


Figure 2
The Eye of Alhazen

This horizontal section through the midlevel of the orbits shows the optic nerves joining behind the eyes at the optic chiasm. The relative curvatures and proportions of the cornea and sclera are fairly accurate, but other features, like the lens and optic nerve head, are not. This eye has no “visual spirit” from which rays might leave the eye to sense external objects. (From Polyak 1941.)